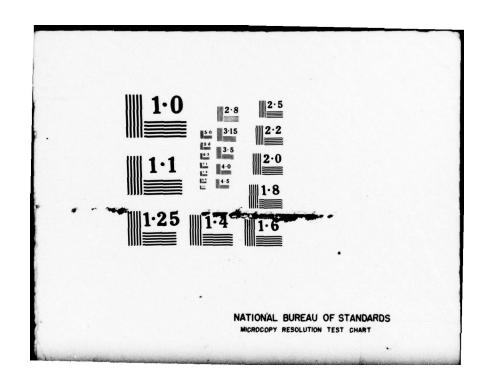
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TECHNICAL REPORT TD-CR-77-5

THEORETICAL ANALYSIS OF THE FLOW FIELD OVER A FAMILY OF OGIVE BODIES

U.S. ARMY
MISSILE
RESEARCH
AND
DEVELOPMENT
COMMAND

Science Applications, Inc. Huntsville, Alabama

16 August 1977

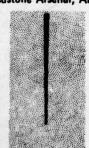


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sof attack; in all other cases only 00 angle of attack was considered. Data are presented for body surface distributions of pressure and Mach number and for wave drag.

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FLOW FIELD

OVER A FAMILY OF OGIVE BODIES

FINAL REPORT

16 August 1977

SCIENCE APPLICATIONS, INC.

2109 West Clinton Avenue, Suite 800 Huntsville, Alabama 35807 (205)533-5900



TABLE OF CONTENTS

Section		Page
1.	INTRODUCTION	. 1
2.	BODY GEOMETRY	. 2
3.	COMPUTER PROGRAM UTILIZATION	. 5
	3.1 Douglas-Newman Program	. 5
	3.3 Barnwell Blunt Body and CONAL Programs	. 7
	Program	. 10 . 12
4.	PRESSURE COEFFICIENT, MACH AND DRAG COEFFICIENT	
	PLOTS	. 14
5.	RESULTS, CONCLUSIONS, AND RECOMMENDATIONS	. 438
6.	REFERENCES	. 440



LIST OF ILLUSTRATIONS

Figure		Page
2-1 2-2	Ogive Body Geometry	2 3
3-1 3-2	TRANS Body Segment Definition	6
3-3	Parameters	8
3-4 4-1	3D MOC Body Segment Definition	10
-031-ND1	Body Shape 1	
4-2	Coefficient of Pressure vs Ogive Length	
4-2 321-811	(Figures 4-2 thru 4-12)	17-28
881	(Figure 4-13)	
thru	(Figures 4-14 and 4-15)	30-31
ocr-est	(Figures 4-16 and 4-17)	
4-23	(Figures 4-18 thru 4-23)	34-39
	Body Shape 2	
4-24	Coefficient of Pressure vs Ogive Length	
	(Figures 4-24 thru 4-34)	41-52
thru	(Figure 4-35)	53
151-138	(Figures 4-36 and 4-37)	
	(Figures 4-38 and 4-39)	56-57
4-45	(Figures 4-40 thru 4-45)	58-63
	Body Shape 3	
4-46	Coefficient of Pressure vs Ogive Length	
	(Figures 4-46 thru 4-56)	65-76
	Vel/Vel Infinity vs Ogive Length (Figure 4-57)	77
thru	(Figures 4-58 and 4-59)	78-80
	(Figures 4-60 and 4-61)	81-82
4-67	(Figures 4-62 thru 4-67)	83-88



Figure		Page
	Body Shape 4	
4-68	Coefficient of Pressure vs Ogive Length (Figures 4-68 thru 4-78)	90-101
	(Figure 4-79)	102
thru	(Figures 4-80 and 4-81)	103-104
	(Figures 4-82 and 4-83)	105-106
4-89	(Figures 4-84 thru 4-89)	107-112
	Body Shape 5	
4-90	Coefficient of Pressure vs Ogive Length	
422	(Figures 4-90 thru 4-100)	114-125
12-02	(Figure 4-101)	126
thru	(Figures 4-102 and 4-103)	127-128
0.0	(Figures 4-104 and 4-105)	129-130
4-111	Mach vs Ogive Length (Figures 4-106 thru 4-111)	131-136
	Body Shape 6	
4-112	Coefficient of Pressure vs Ogive Length	
7-110	(Figures 4-112 thru 4-122)	138-149
65	Vel/Vel Infinity vs Ogive Length	
	(Figure 4-123)	150
66~66	Mach vs Ogive Length	
thru	(Figures 4-124 and 4-125)	151-152
10.494	Vel/Vel Infinity vs Ogive Length	
	(Figures 4-126 and 4-127)	153-154
63-86	Mach vs Ogive Length	
4-133	(Figures 4-128 thru 4-133)	155-160
	Body Shape 7	
4-134	Coefficient of Pressure vs Ogive Length	
	(Figures 4-134 thru 4-144)	162-173
	Vel/Vel Infinity vs Ogive Length (Figure 4-145)	174
Sale Sec	Mach vs Ogive Length	***
thru	(Figures 4-146 and 4-147)	175-176
	Vel/Vel Infinity vs Ogive Length	
	(Figures 4-148 and 4-149)	177-178
	Mach vs Ogive Length	
4-155	(Figures 4-150 thru 4-155)	179-184



Figure		Page
	Body Shape 8	
4-156	Coefficient of Pressure vs Ogive Length	
12293	(Figures 4-156 thru 4-166)	186-197
18	(Figure 4-167)	198
thru	Mach vs Ogive Length (Figures 4-168 and 4-169)	199-200
895-18	Vel/Vel Infinity vs Ogive Length (Figures 4-170 and 4-171)	201-202
4-177	Mach vs Ogive Length (Figures 4-172 thru 4-177)	203-208
	Body Shape 9	
4-178	Coefficient of Pressure vs Ogive Length	
718-80	(Figures 4-178 thru 4-188)	210-221
87	(Figure 4-189)	222
thru	(Figures 4-190 and 4-191)	223-224
888-17	Vel/Vel Infinity vs Ogive Length (Figues 4-192 and 4-193)	225-226
4-199	Mach vs Ogive Length (Figures 4-194 thru 4-199)	227-232
	Body Shape 10	
4-200	Coefficient of Pressure vs Ogive Length	
-148-AD	(Figures 4-200 thru 4-210)	234-245
	(Figure 4-211)	246
thru	Mach vs Ogive Length (Figures 4-212 and 4-213)	247-248
0.000 - 1.00	Vel/Vel Infinity vs Ogive Length (Figures 4-214 and 4-215)	249-250
4-217	Mach vs Ogive Length (Figures 4-216 thru 4-221)	251-256
906 SM	Body Shape 11	4-310 (
4-222	Coefficient of Pressure vs Ogive Length	
1-222	(Figures 4-222 thru 4-232)	258-269
	Vel/Vel Infinity vs Ogive Length (Figure 4-233)	270
thru	Mach vs Ogive Length (Figures 4-234 and 4-235)	271-272
	Vel/Vel Infinity vs Ogive Length (Figures 4-236 and 4-237)	273-274
4-243	Mach vs Ogive Length (Figures 4-238 thru 4-243)	275-280
		7

Figure		Page
	Body Shape 12	
4-244	Coefficient of Pressure vs Ogive Length (Figures 4-244 thru 4-254) Vel/Vel Infinity vs Ogive Length	. 282-293
	(Figure 4-255)	. 294
thru	(Figures 4-256 and 4-257)	. 295-296
\$20 to 11	(Figures 4-258 and 4-259)	. 297-298
4-265	(Figures 4-260 thru 4-265)	299-304
	Body Shape 13	
4-266	Coefficient of Pressure vs Ogive Length (Figures 4-266 thru 4-276)	306-317
abcues	(Figure 4-277)	. 318
thru	(Figures 4-278 and 4-279)	. 319-320
ese es	(Figures 4-280 and 4-281)	. 321-322
4-287	Mach vs Ogive Length (Figures 4-282 thru 4-287)	. 323-328
	Body Shape 14	
4-288	Coefficient of Pressure vs Ogive Length (Figures 4-288 thru 4-299)	. 330-341
47-248	(Figure 4-300)	. 342
thru	(Figures 4-301 and 4-302)	. 343-344
946-10	(Figures 4-303 and 4-304)	. 345-346
4-310	(Figures 4-305 thru 4-310)	. 347-352
988-269	efficient of prosents vs Ogive Length Signres 4-232 thre 4-232). Market Justitity vs Ogive Length	
	Control 1-2331	
173 - 272 172 - 278	elegros 4-231 and 6-235)	
778 2879 90	Pindres 4-238 and 6-237)	



Figure		Page
	Body Shape 15	
4-311	Coefficient of Pressure vs Ogive Length	
130	(Figures 4-311 thru 4-322)	354-365
	Vel/Vel Infinity vs Ogive Length (Figure 4-323)	366
150	Mach vs Ogive Length	000
	(Figures 4-324 and 4-325)	367-368
thru	Vel/Vel Infinity vs Ogive Length	
183	(Figure 4-326)	369
	Mach vs Ogive Length	370-375
434	(Figures 4-327 thru 4-332)	310-313
4-333	(Figure 4-333)	376
- 555	11 01-70	
336	Body Shape 16	
4-334	Coefficient of Pressure vs Ogive Length	
TEA	(Figures 4-334 thru 4-345)	378-389
	Vel/Vel Infinity vs Ogive Length	
	(Figure 4-346)	390
thru	Mach vs Ogive Length (Figures 4-347 and 4-348)	391-392
1910 073	Vel/Vel Infinity vs Ogive Length	001 002
	(Figures 4-349 and 4-350)	393-394
	Mach vs Ogive Length	1.0
4-356	(Figures 4-351 thru 4-356)	395-400
	Body Shape 17	
4-357	Coefficient of Pressure vs Ogive Length	
	(Figures 4-357 thru 4-368)	402-413
	Vel/Vel Infinity vs Ogive Length	434
	(Figure 4-369)	414
thru	(Figures 4-370 and 4-371)	415-416
	Vel/Vel Infinity vs Ogive Length	
	(Figures 4-372 and 4-373)	417-418
	Mach vs Ogive Length	
4-379	(Figures 4-374 thru 4-379)	419-424
4-380	Coefficient of Drag vs Mach Number	
1-000	BS-1,2,3 M.8-4.5 AO	426
4-381	Coefficient of Drag vs Mach Number	
	BS-4,5,6 M.8-4.5 AO	427
4-382	Coefficient of Drag vs Mach Number	400
	BS-7,8,9 M.8-4.5 AO	428



Figure									Page
4-383	Coefficient of Drag vs BS-10,11,12 M.8-4.5 AO		00					•	429
4-384	Coefficient of Drag vs BS-13 M.8-4.5 AO								430
4-385	Coefficient of Drag vs BS-17 M.8-4.5 AO	Mach Number	13. 23.						431
4-386	Coefficient of Drag vs BS-1,2,3 M2-4.5 A2	Mach Number	25		8	u le u-T			432
4-387	Coefficient of Drag vs	Mach Number					1		
4-388	BS-4,5,6 M2-4.5 A2 Coefficient of Drag vs	Mach Number		•	0		in tou		433
4-389	BS-7,8,9 M2-4.5 A2 Coefficient of Drag vs	Mach Number			•	1	٠	H	434
4-390	BS-10,11,12 M2-4.5 A2. Coefficient of Drag vs		•	•	•	•	•		435
4-391	BS-13 M2-4.5 A2 Coefficient of Drag vs			7 34		91		· 69	436
	BS-17 M2-4.5 A2		٠	•					437
1096									
261-165									uni
Table									Page
2-1	List of Body Shapes	disperie				·		No.	4



1. INTRODUCTION

The overall objective of this study is the calculation, analysis, and presentation of the flow field around selected ogive bodies at various Mach numbers and two angles of attack. The results of the study are pressure coefficient and body normal forces for the various bodies. The Mach number range of interest is from subsonic, M_0.5, to the high supersonic, M_5. Analysis presentation includes plots of pressure and Mach number distribution, and drag coefficient as a function of free stream Mach number.

A total of 17 bodies are considered in this report. Sixteen of the bodies have bluntness ratios from 0 to 1 and fineness ratios from 4 to .5 (see Figure 2-1). The seventeenth body (Special Body N27, see Figure 2-2) is characterized by specified dimensions. The body geometries for the 17 shapes are given in Section 2.

In Section 3 the computer simulations used to obtain the plotted data are discussed, including the body shape input requirements.

Aerodynamic curves for all the body shapes are presented in Section 4. The plots are for free stream Mach numbers from 0 to 4.5, and angles of attack of 0 and 2 degrees. The body shapes have been normalized with the diameter of the attached cylinder considered to be unity. Also included in Section 4 are plots of drag coefficient of each body as a function of Mach Number.

Section 5 consists of a brief discussion of the problems encountered during the study and discussion of the resulting plots, conclusions drawn, and recommendations for possible further study.

Last, a list of references is included. This consists primarily of the documentation supporting the computer simulations utilized.

2. BODY GEOMETRY

A total of 17 ogive body shapes are considered in this report. Sixteen of them are characterized by bluntness ratios from 0 to 1 and fineness ratios from 4 to .5.

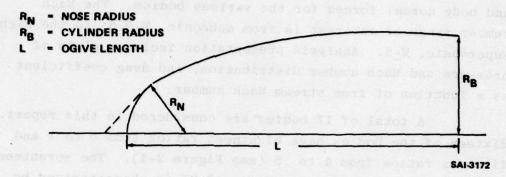


Figure 2-1. Ogive Body Geometry

From Figure 2-1, the bluntness ratio is defined as the nose radius divided by the attached cylindrical body radius:

Bluntness =
$$\frac{R_N}{R_B}$$

In this report bluntness ratios of 0, .2, .4, .6, .8 and 1 are considered, where a bluntness of 0 is a sharp ogive and of bluntness of 1 is a hemispherical ogive. Also from Figure 2-1, the fineness ratio is defined as the ogive body length divided by the diameter of the attached cylinder:

Fineness =
$$\frac{L}{2R_B}$$

Fineness ratios of 4, 3, 2 and .5 are considered in this report, where a fineness ratio of 1 is a hemispherical ogive. The body shapes are normalized with the cylinder diameter, considered to be unity.



The 17th ogive body is defined by a specified nose radius, cylinder radius, length and cone half angle as indicated in Figure 2-2.

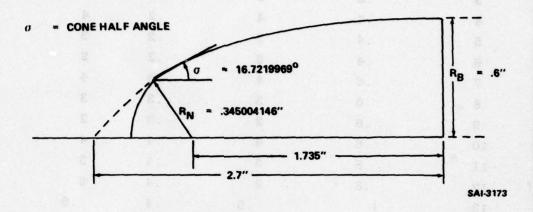


Figure 2-2. Special Body N27

Listed below in Table 2-1 are the 17 body shapes this report considers, along with the bluntness and fineness ratios of each body (except for body shape 17). Also listed are values of $R_{\rm N}$ and L.

BODY SHAPE	BLUNTNESS	FINENESS	R _N	L
et	RATIO	RATIO	September 1	holles anime
.1	.2	4	5-8 949	will at bottomi
2	.2	3	.1	3
3	.2	2	.1	2
4	.4	4	.2	4
5	.4	3	.2	3
6	.4	2	.2	2
7	.6	4	.3	4
8	.6	3	.3	3
9	.6	2	.3	2
10	.8	4	.4	4
11	.8	3	.4	3
12	.8	2	.4	2
13	1	.5	.4	. 5
14	0	4	0	4
15	0	3	0	3
16	0 4 4508	2	0	2
17	_	-	.345004146	2.080004146

TABLE 2-1. LIST OF BODY SHAPES

3. COMPUTER PROGRAM UTILIZATION

Several computer simulations were required to generate the pressure coefficient, Mach and drag coefficient data plotted in Section 4, depending upon the free stream Mach number being considered and whether the body shape has a blunted or sharp nose. These programs are discussed separately, including body shape input requirements and output data.

3.1 DOUGLAS-NEUMANN PROGRAM

The Douglas-Neumann Program is used for low free stream Mach numbers (.6 or lower). With body shapes input either as an array of points, as generated ellipsoids, or as generated bodies with elliptical cross sections, the program will calculate the total velocity (normalized with the free stream velocity, V infinity) and pressure coefficient as functions of the distance from the nose along the body. For this study, free stream Mach numbers of 0 (incompressible case) and .6 were used and all bodies were input as generated bodies with elliptical cross sections.

For anything greater than Mach 0, a Mach correction is applied, resulting in "stretching" the body axially to account for the input free stream Mach number. Since this correction is applied axially along the body, there is no provision for considering an angle of attack when a Mach correction is applied. Thus, to obtain data for the Mach .6 case with angle of attack 2°, a combination of two runs was necessary. The axial flow case of Mach .6 was combined vectorially with a vertical flow case of Mach 0 at each point along the body and the approximate velocities and pressure coefficients were calculated as follows:



$$V_T = V_T \text{ axial } x \cos 2^{\circ} + V_T \text{ vertical } x \sin 2^{\circ}$$

$$CP = \sqrt{1 - V_T^2}$$

where V_T = total velocity, normalized with V infinity CP = coefficient of pressure.

3.2 TRANS PROGRAM

The TRANS Program is utilized for free stream Mach numbers around 1. In this study Mach numbers of .8, .9, .95, 1.0, 1.05 1.1, and 1.2 were considered. There are no provisions for considering cases with angles of attack applied; therefore only the 0 angle of attack cases were developed. Bodies are input in segments, and all segments are considered to be uniform with respect to the longitudinal axis.

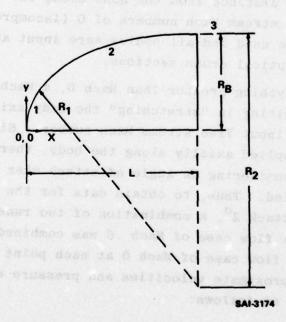


Figure 3-1. TRANS Body Segment Definition

Sil

For the blunt nose ogive body shape there are three separate body segments. Each segment is input by specification of constants A through F in the equation

$$Ay^2 + Byx + Cx^2 + Dy + Ex + F = 0.$$

From Figure 3-1, Body Segment is input as the arc of a circle of radius R with the origin at $(R_1,0)$ and satisfies the equation

$$(y - 0)^2 + (x - R_1)^2 = R_1^2$$

Thus, the constants A and C are one and the constants B, D and F are zero, resulting in an equation of the form

$$y^2 + x^2 + Ex = 0.$$

Similarly, Body Segment 2 is input as the arc of a circle of radius R_2 with the origin at $(L,(R_B-R_2))$, and satisfies the equation

$$[y-(R_B-R_2)]^2 + (x-L)^2 = R_2^2$$

Thus, the constants A and C are one, and the constant B is zero, resulting in an equation of the form

$$y^2 + x^2 + Dy + Ex + F = 0$$
.

The third body segment is defined as a straight line parallel to the x axix, depicting the cylinder attached to the ogive. Thus, from Figure 3-1, Body Segment 3 satisfies the equation

$$y = R_B$$

where the constants A, B, C and E are zero.



TRANS outputs the coefficient of pressure and Mach as a function of the distance from the tip of the nose (from Figure 3-1, x along the body). Also the drag coefficient is calculated as a function of the input of free stream Mach number. A description of the TRANS program is provided in Reference 1.

3.3 BARNWELL BLUNT BODY AND CONAL PROGRAMS

Programs used for calculating flow at high free stream Mach numbers (2 and greater) are very sensitive to where the shock wave attaches to the nose of the ogive body shape. They must have pressure data from the nose tip past where the shock wave attaches to ensure stability. This data is generated by an intermediate program. The program used for all blunt nose cases is the Barnwell Blunt Body Program (BBB) whereas, the CONAL Program is used for all sharp nose cases.

Input to BBB is accomplished through NAMELIST. A reference surface of the body is defined, and body segments are input as radii of curvature.

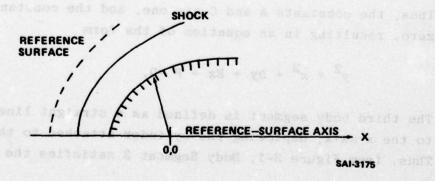


Figure 3-2. Barnwell Blunt Body Coordinates and Geometric Parameters



A nonorthogonal computational coordinate system is used. This coordinate system is oriented with respect to a reference surface (see Figure 3-2) which is symmetric about an axis and which has a generator composed of segments of constant curvature (circular arcs and straight-line segments). Execution of the BBB Program requires the input of the initial shock shape as specified by the equation

$$R^2 = -2R_S X - B_S X^2$$

where R_S is the nose radius of curvature and B_S is the bluntness. These shock parameters are obtained from constants given in Reference 2 as a function of free stream Mach number. The body shapes input to the BBB Program are normalized with the nose radius, considered to be unity.

For a more thorough understanding of input specifications and the theory on which the BBB Program is based, see Reference 3.

Input to the CONEAL Program consists of specifying the cone half angle, J_{C} (see Figure 3-3), free stream Mach number and initial and final angles of attack.

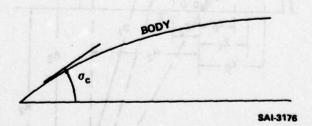


Figure 3-3. CONAL Cone Half Angle



Output of both programs consists of an array of pressure distributions as a function of distance from the ogive body nose tip. These arrays are input to the GASL Three-Dimensional Method of Characteristics Program as initial conditions. This program is discussed next.

3.4 THREE-DIMENSIONAL METHOD OF CHARACTERISTICS PROGRAM

The GASL 3D Method of Characteristics Program

(3D MOC) is initiated with the pressure distributions developed
by the BBB and CONEAL Programs. Body shapes are input in
geometric segments, satisfying the equation

$$R = HZ^{3} + KZ^{2} + AZ + B$$
or
$$R = K + B \sqrt{1 - \left(\frac{Z-H}{A}\right)^{2}}$$

For example, a blunt nosed ogive body shape is input in the following manner.

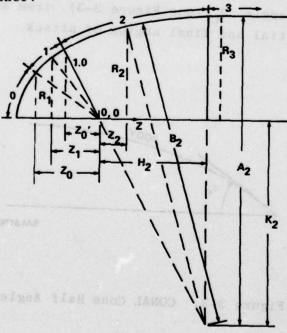


Figure 3-4. 3D MOC Body Segment Definition



Section O is not input. The pressure distribution for the section (from the nose tip to Z_{0-} is determined by BBB or CONEAL and input to the 3D MOC Program via magnetic tape. Section 1, from Z_{0} to Z_{0} , is input in the form

$$R_1 = K_1 + B_1 \sqrt{1 - \left(\frac{Z-H}{A_1}\right)^2}$$

where the constants K_1 and H_1 are zero, and the constants B_1 and A_1 are one. Thus,

$$R_1 = \sqrt{1 - \left(Z_1\right)^2}$$

As noted from Figure 3-4, the body dimensions have been normalized by allowing the nose radius to be unity.

Body Segment 2 is input in the form

$$R_2 = K_2 + B_2 \sqrt{1 - \left(\frac{Z_2 - H_2}{A_2}\right)^2}$$

where K_2 , B_2 , Z_2 , H_2 and A_2 are defined in Figure 3-4.

The constants are normalized with the nose radius, considered to be unity.

Body Segment 3 is input as a straight line in the form

$$R_3 = H_3 Z_3^3 + K_3 Z_3^2 + A_3 Z_3 + B_3$$

where H_3 , K_3 and A_3 are zero and B_3 equals the radius of the attached cylinder, normalized with the nose radius.

Since for the sharp nosed body shapes the nose radius is zero, these bodies are normalized with the attached cylinder diameter.



The output of the 3D MOC Program consists of pressure distribution arrays over the entire ogive body. These arrays are read to magnetic tape for use in the next program discussed, the Aerodynamic Coefficients Program. Reference 4 discusses the 3D MOC Program and its uses in detail.

3.5 AERODYNAMIC COEFFICIENTS PROGRAM

The Aerodynamic Coefficients Program (AC) is used to obtain aerodynamic coefficients from pressure distributions output by the 3D MOC Program. The parameters input to AC include the cone half angle (as defined in Figure 2-2), angle of attack, free stream Mach number, and reference length or nose radius. The program calculates the coefficient of pressure and Mach as a function of the distance from the origin (as defined in Figure 3-4). Also, AC calculates the drag coefficient as a function of free stream Mach number.

Reference 5 contains a thorough description of the Aerodynamics Coefficients Program, including the theory and complete input requirements.



4.0 PRESSURE COEFFICIENT, MACH AND DRAG COEFFICIENT PLOTS

Section 4.0 contains all of the data plots generated by the DN, TRANS and AC Programs. The pressure coefficient and Mach plots are arranged by body shape number, with the plots for an angle of attack of zero degrees preceeding those for an angle of attack of two degrees. Following the plots for each body shape are the Coefficient of Drag vs Free Stream Mach Number plots for all of the body shapes.

One set of plots for a body shape consists of the following:

Coefficient of Drag vs Ogive Length

for

Mach 0, .6 Alpha 0

Mach .8, .9, .95, 1.0, 1.05, 1.1, 1.2 Alpha 0

Mach 2., 2.5, 3., 3.5, 4., 4.5 Alpha 0

Mach 0 Alpha 2

Mach .6 Alpha 2

Mach 2.0 Alpha 2

Mach 2.5 Alpha 2

Mach 3.0 Alpha 2

Mach 3.5 Alpha 2

Alpha 2 Mach 4.0

Mach 4.5 Alpha 2

Velocity/Velocity Infinity vs Ogive Length

for

Mach 0, .6 Alpha 2

Mach vs Ogive Length

for

Mach .8, .9, .95, 1.0, 1.05, 1.1, 1.2 Alpha 0

Mach 2., 2.5, 3., 3.5, 4., 4.5 Alpha 0



Velocity/Velocity Infinity vs Ogive Length for

Mach 0 Alpha 2

Mach .6 Alpha 2

Mach vs Ogive Length

for

Mach 2.0 Alpha 2 Mach 2.5 Alpha 2

Mach 3.0 Alpha 2

Mach 3.5 Alpha 2

Mach 4.0 Alpha 2

Mach 4.5 Alpha 2

The following symbols are used on the plots.

Symbol	Meaning
M	Mach
A	Angle of Attack
Alpha	Angle of Attack
Theta	Angle measured from center of body at each point on the body - applicable only for angle of attack plots (see Figure 4-1)
BS	Body Shape
0, X, ,Y, +,*,L	Plot symbols representing first line through seventh line, respectively, plotted

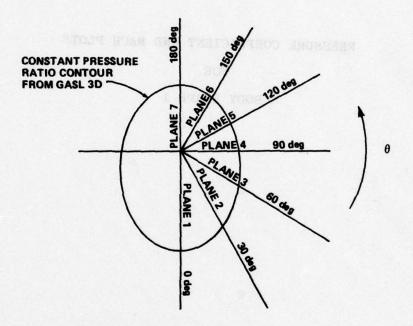
For example, the plot titled

"BODY SHAPE 1 MACH 2 ALPHA 2 THETA 0, 60, 120, 180" has "O", "X", " ", and "Y" plot symbols representing the theta = 0, 60, 120 and 180 lines, respectively.

Similarly, the plot titled

"BODY SHAPE 1 MACH 2., 2.5, 3., 3.5, 4., 4.5 ALPHA 0" has "0", "X", " ", "Y", "+" and "*" symbols representing the Mach 2, 2.5, 3, 3.5, 4 and 4.5 lines, respectively.





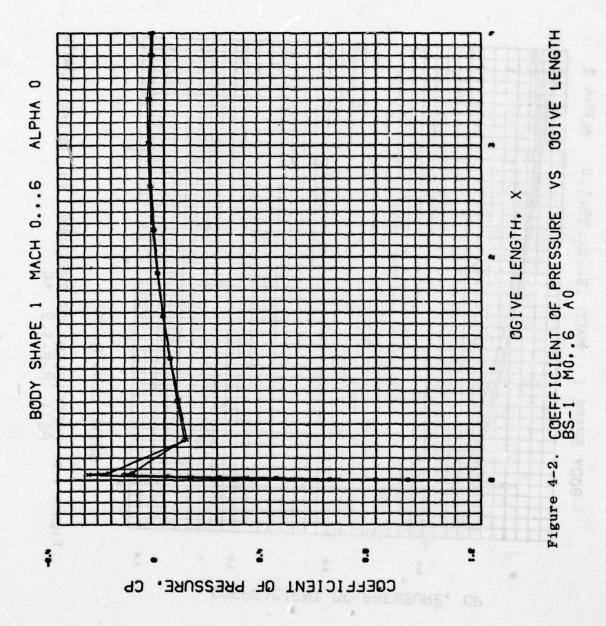
POLAR SECTION AT CONSTANT AXIAL STATION Z (BODY COORDINATES, SEE REFERENCE 5)

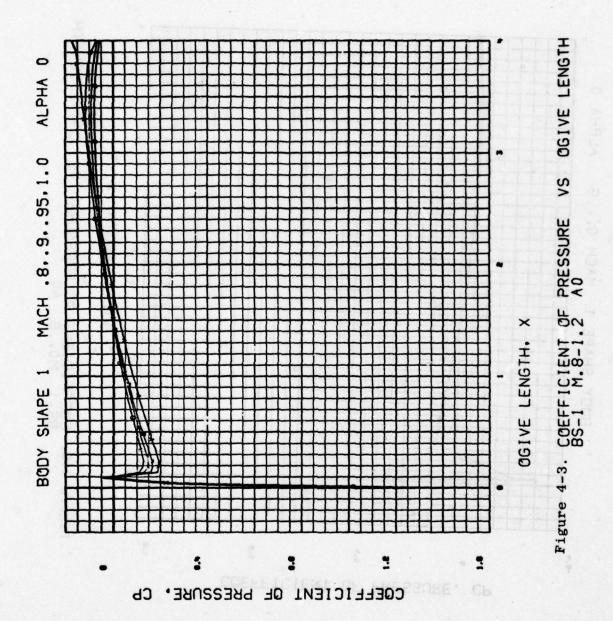
Figure 4-1. Definition of Theta



PRESSURE COEFFICIENT AND MACH PLOTS
FOR

BODY SHAPE 1





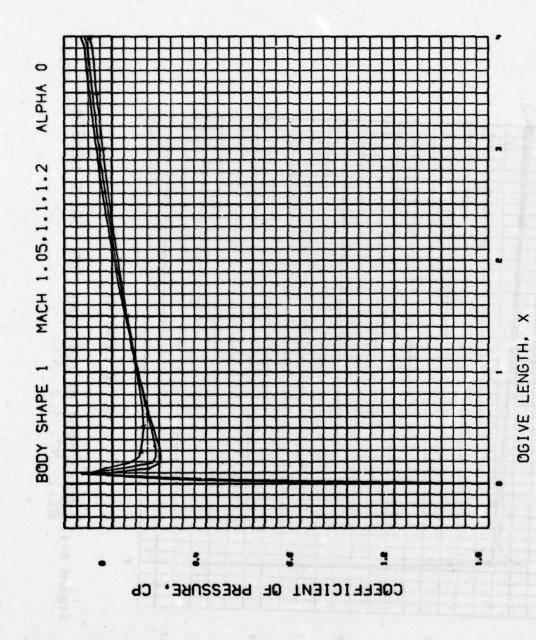
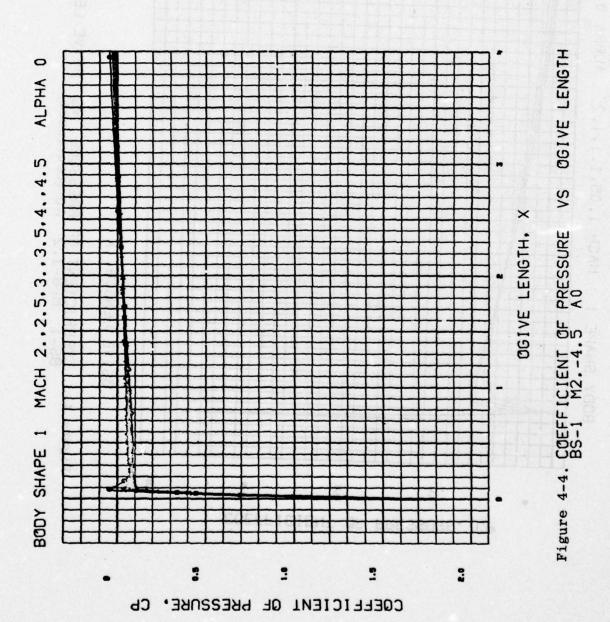
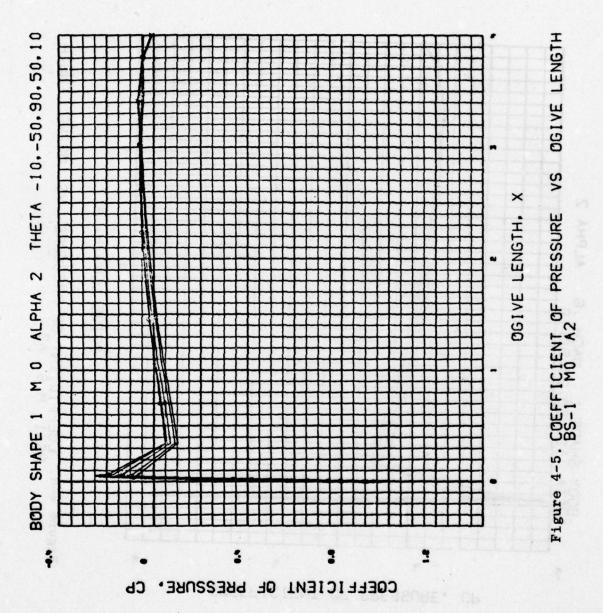
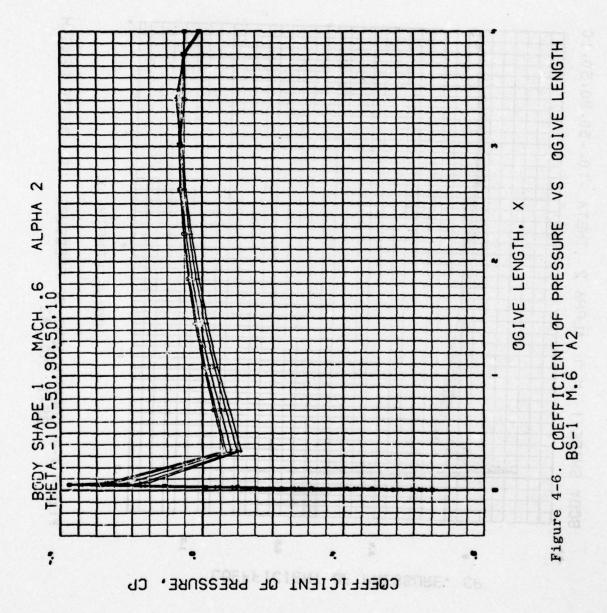
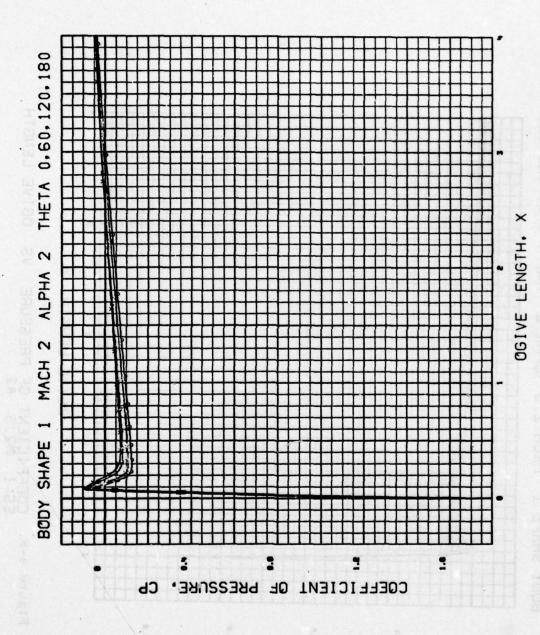


Figure 4-3. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-1 M.8-1.2 A0 (Continued)

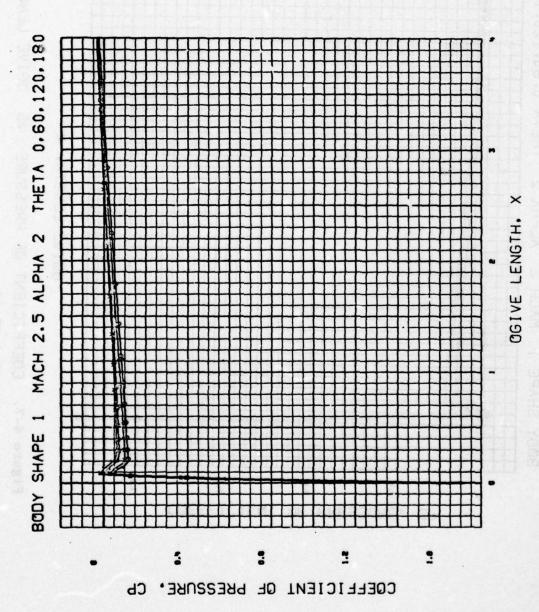




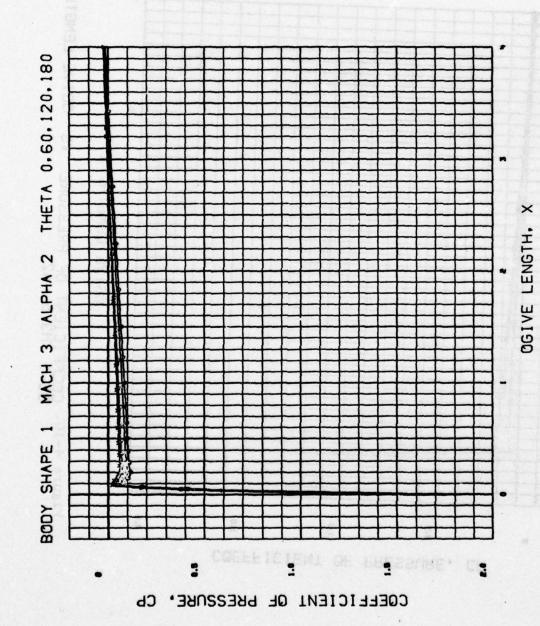




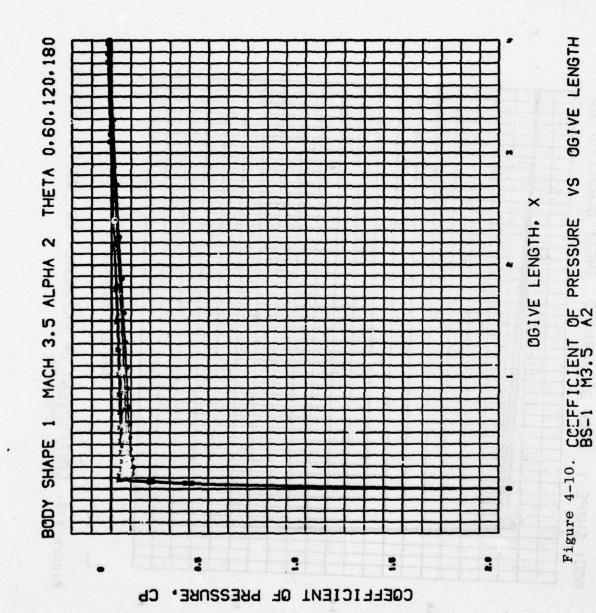
COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-1 M2 A2 Figure 4-7.

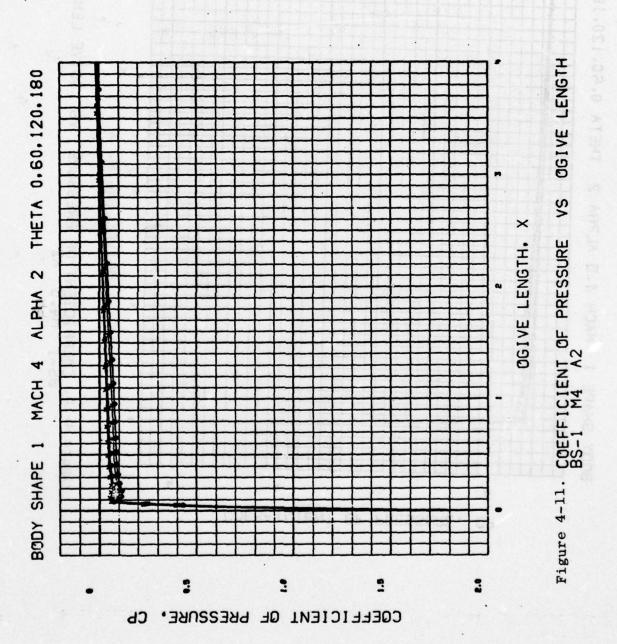


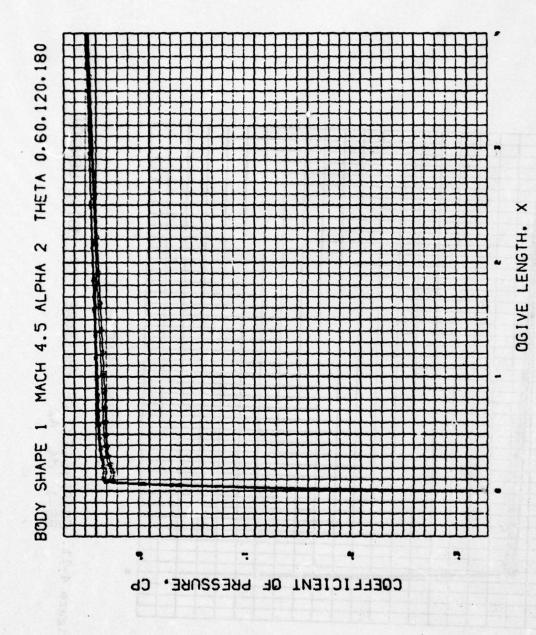
COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-1 M2.5 A2 Figure 4-8.



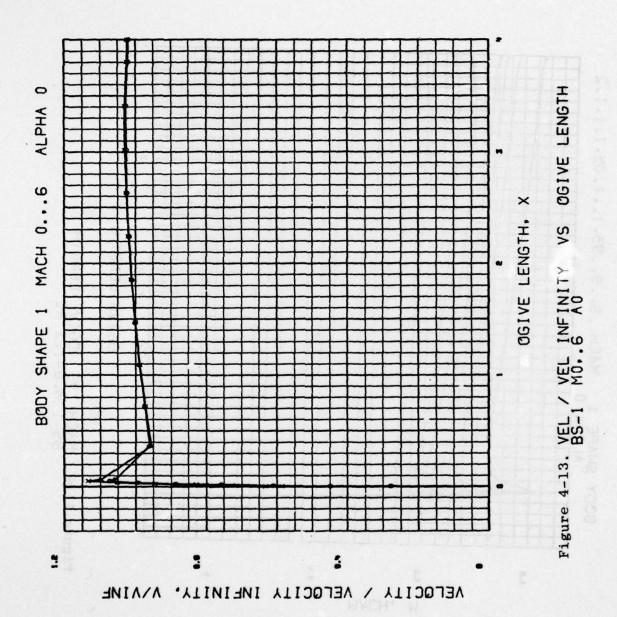
COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-1 M3 A2 Figure 4-9.

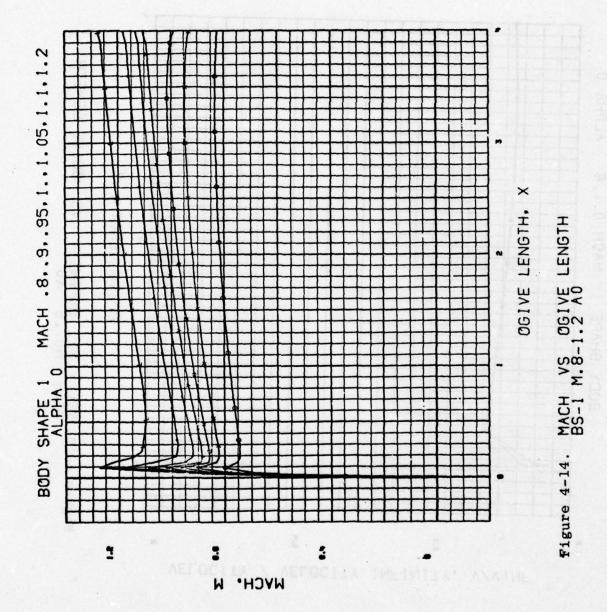






OGIVE LENGTH Figure 4-12. COEFFICIENT OF PRESSURE VS BS-1 M4.5 A2





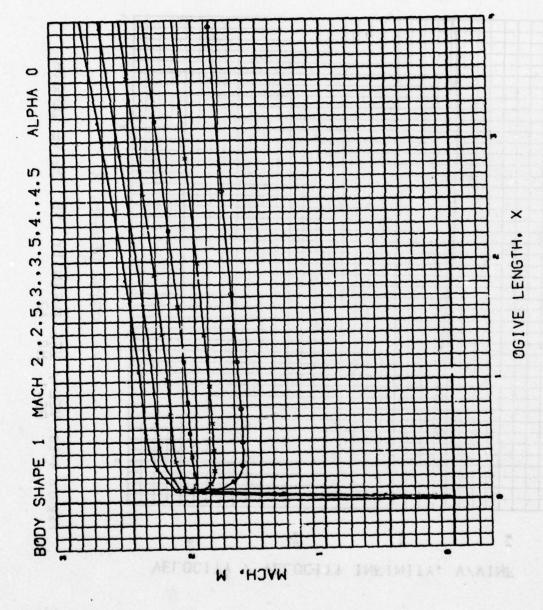


Figure 4-15. MACH VS OGIVE LENGTH BS-1 M2.-4.5 AO

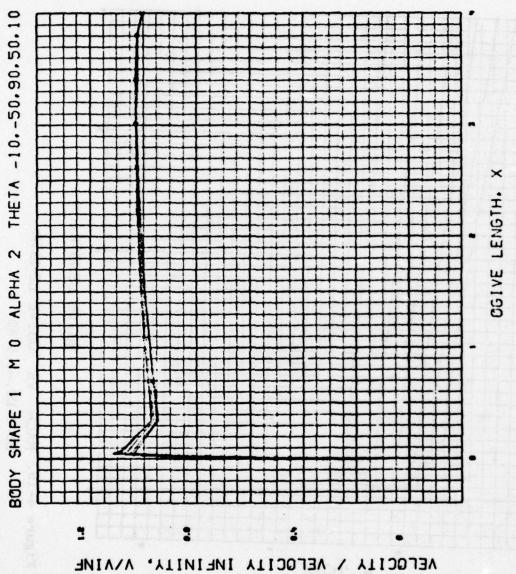


Figure 4-16. VEL / VEL INFINITY VS OGIVE LENGTH BS-1 M0 A2

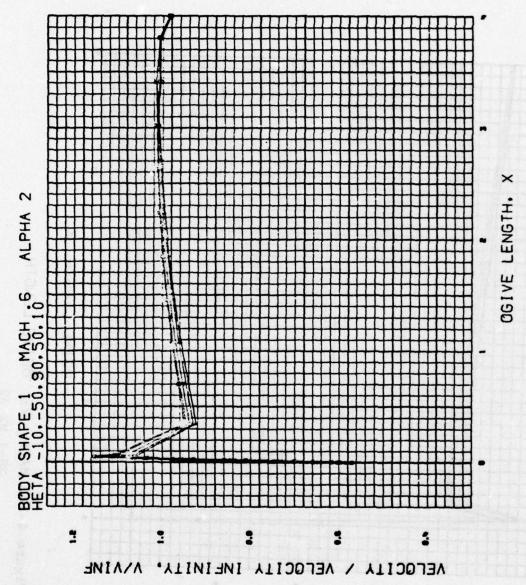


Figure 4-17. VEL / VEL INFINITY VS OGIVE LENGTH BS-1 M.6 A2

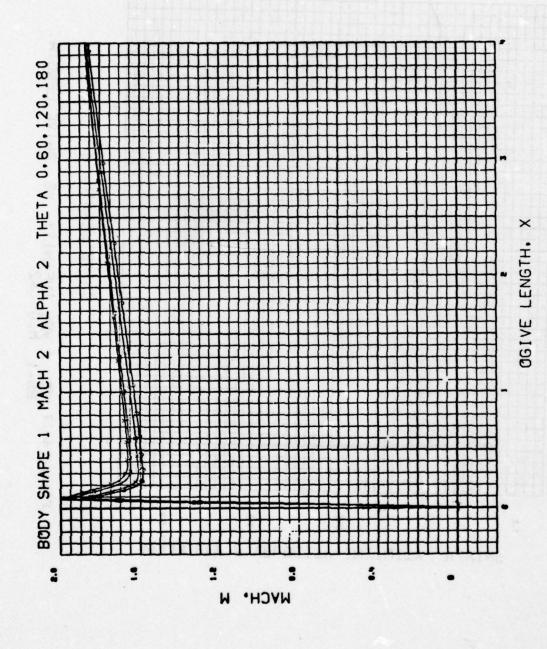


Figure 4-18. MACH VS OGIVE LENGTH BS-1 M2 A2

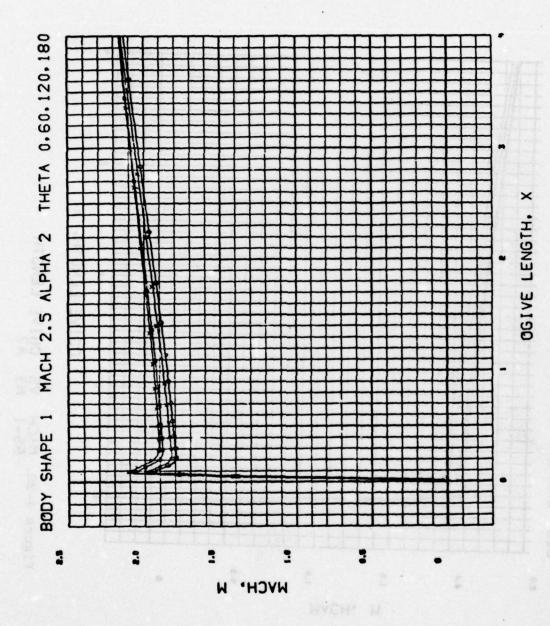
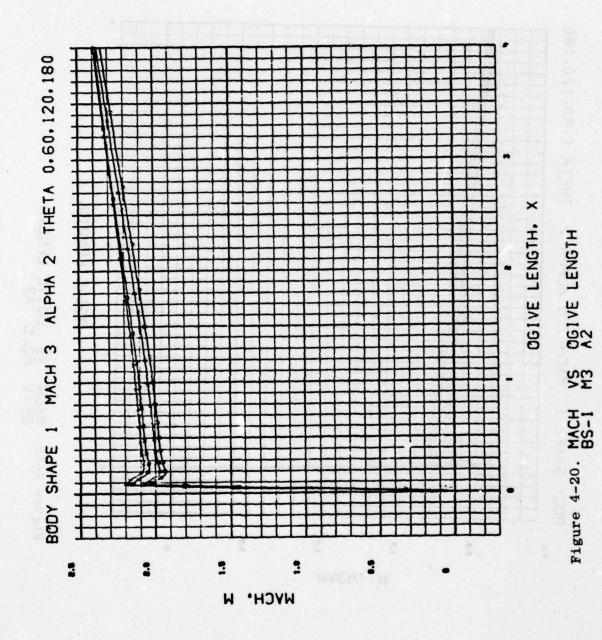


Figure 4-19. MACH VS OGIVE LENGTH BS-1 M2.5 A2



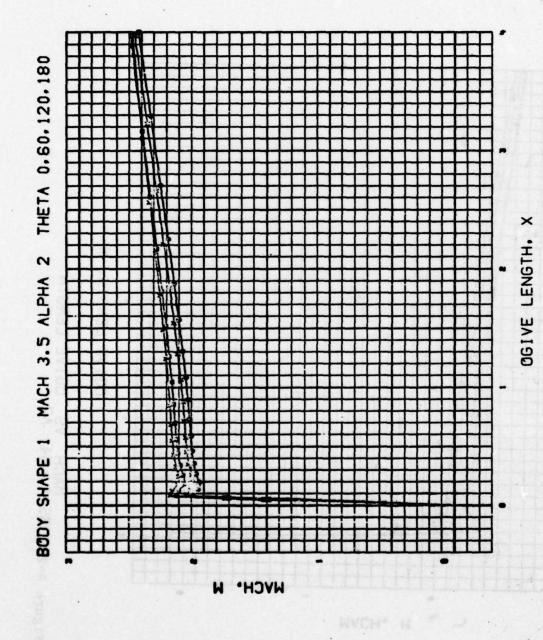


Figure 4-21. BS-1 M3.5 A2

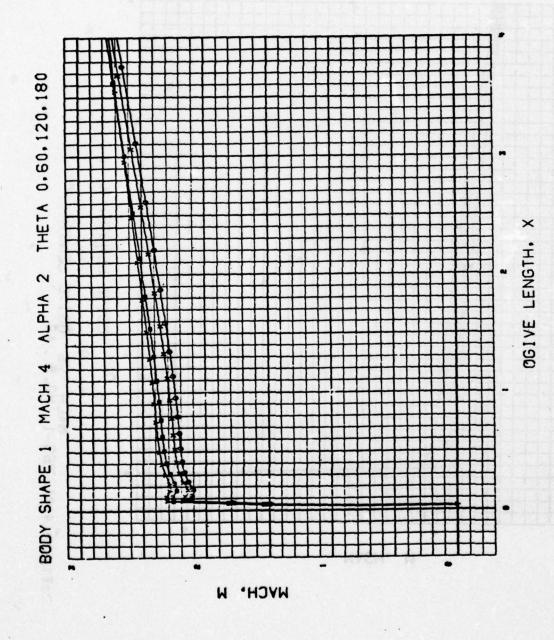


Figure 4-22, BS-1 M4 A2 OGIVE LENGTH

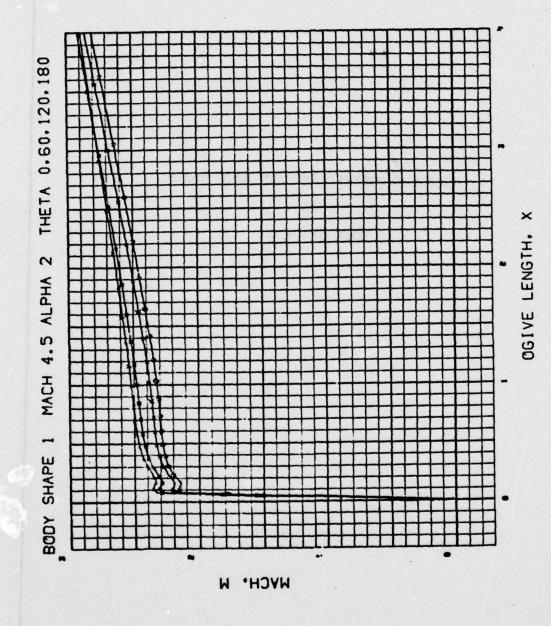


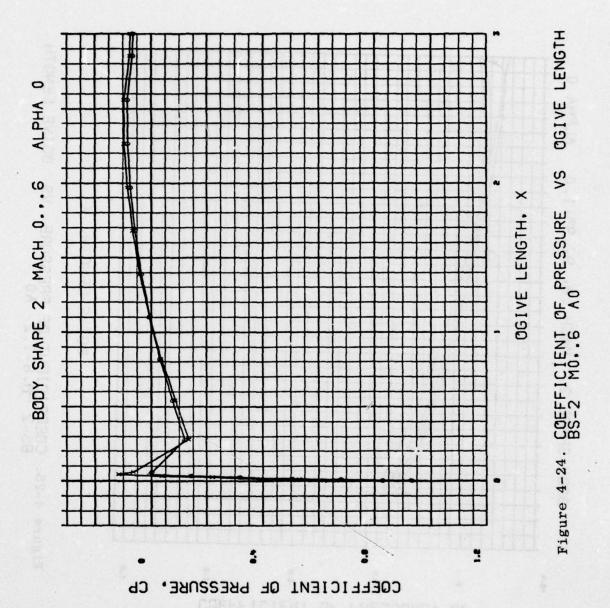
Figure 4-23. BS-1 M4.5 A2

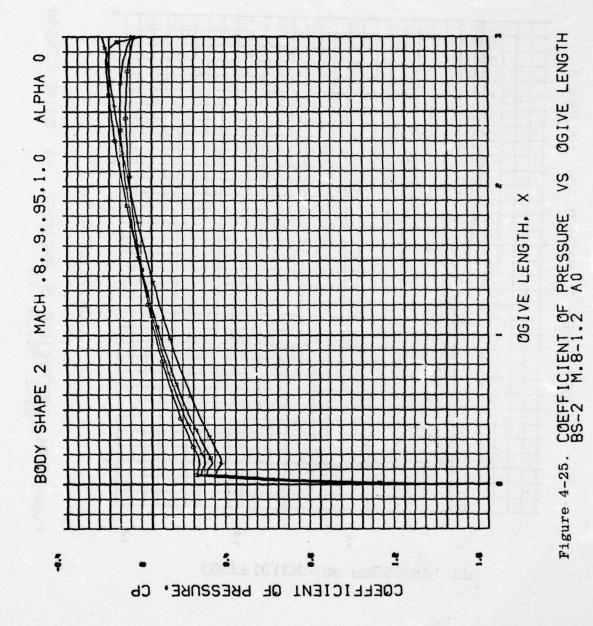
PRESSURE COEFFICIENT AND MACH PLOTS

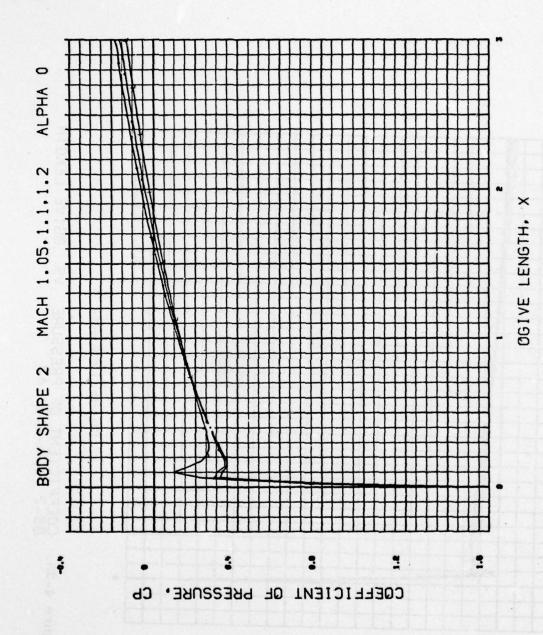
FOR

BODY SHAPE 2

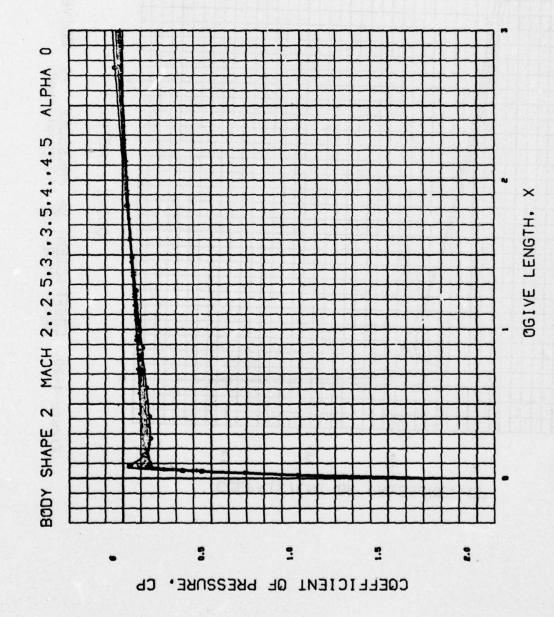




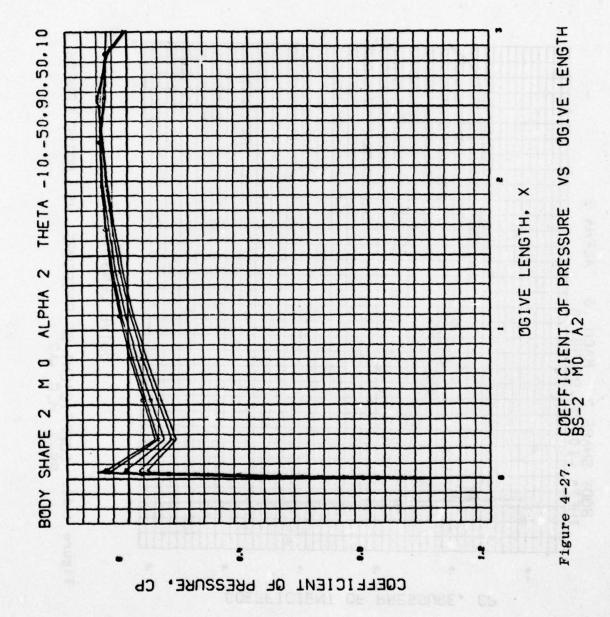


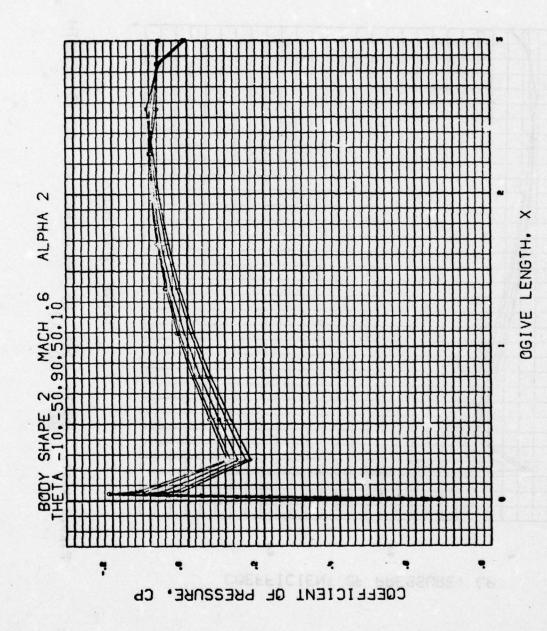


COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-2 M.8-1.2 A0 (Continued) Figure 4-25.



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-2 M2.-4.5 A0 Figure 4-26.



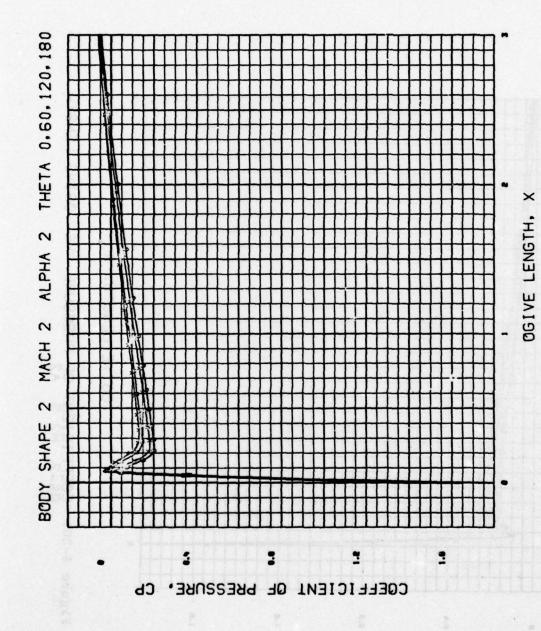


OGIVE LENGTH

SA

Figure 4-28. COEFFICIENT OF PRESSURE BS-2 M.6 A2

46



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-2 M2 A2 Figure 4-29.

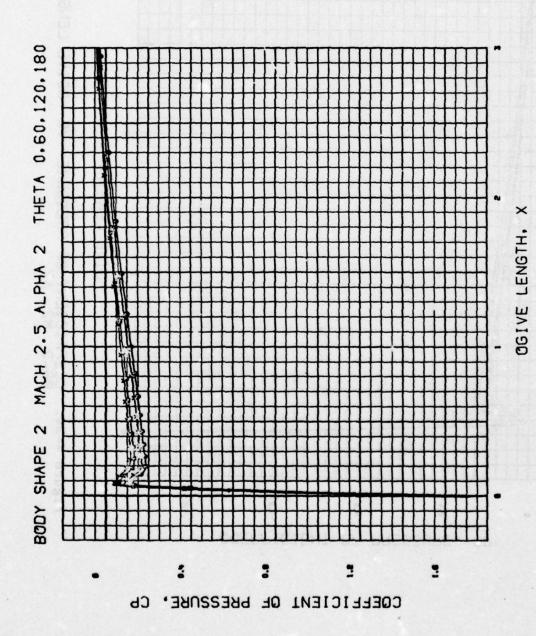
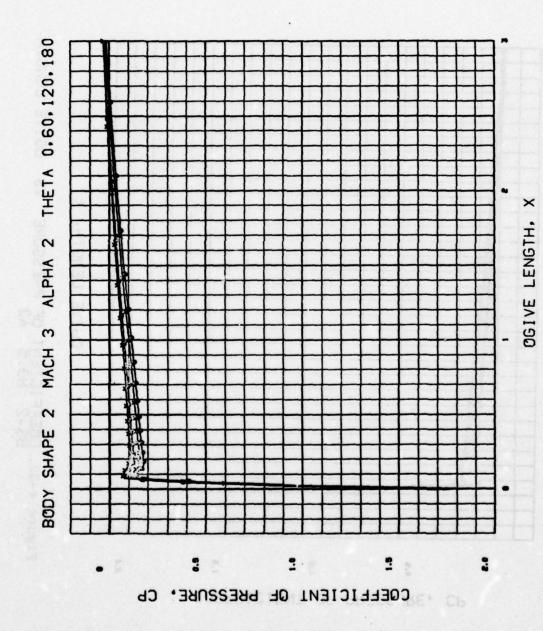
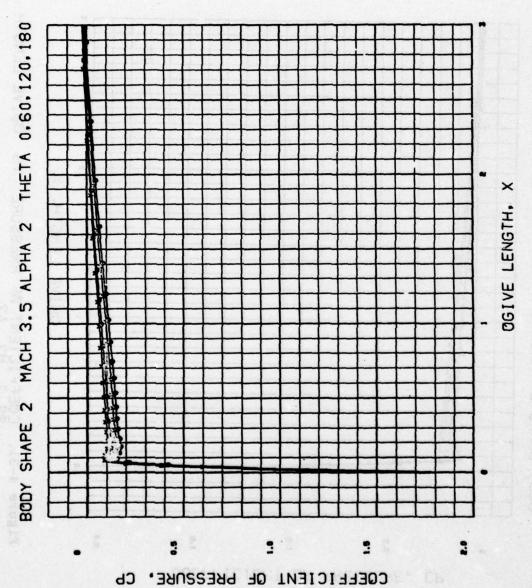


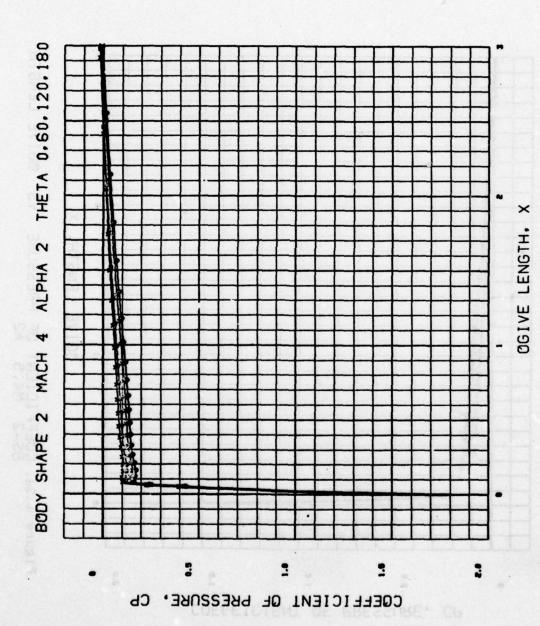
Figure 4-30. COEFFICIENT OF PRESSURE VS OGIVE LENGTH



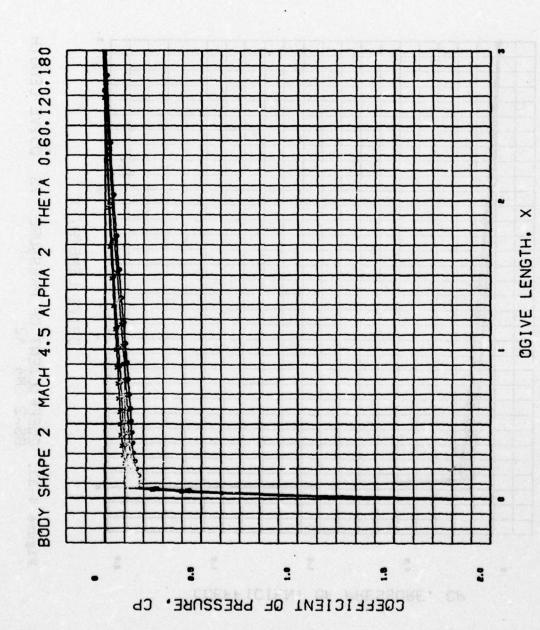
OGIVE LENGTH ٧S Figure 4-31. COEFFICIENT OF PRESSURE BS-2 M3 A2



OGIVE LENGTH ۸S Figure 4-32. COEFFICIENT OF PRESSURE BS-2 M3.5 A2



OGIVE LENGTH Figure 4-33. COEFFICIENT OF PRESSURE VS BS-2 M4 A2



VS OGIVE LENGTH Figure 4-34. COEFFICIENT OF PRESSURE BS-2 M4.5 A2

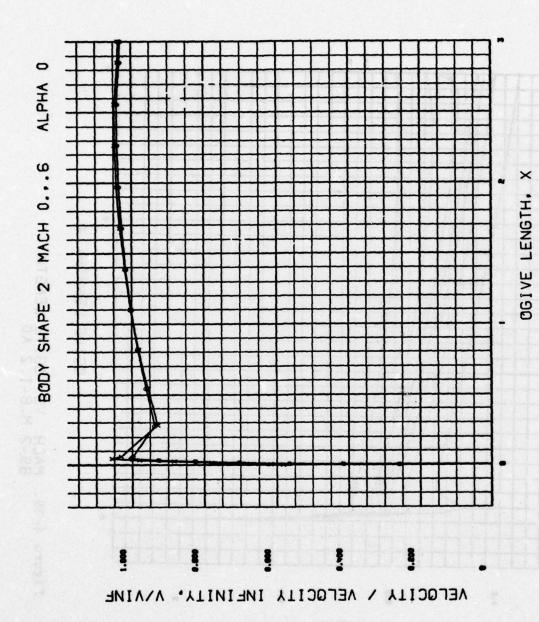


Figure 4-35. VEL / VEL INFINITY VS OGIVE LENGTH BS-2 M0..6 A0

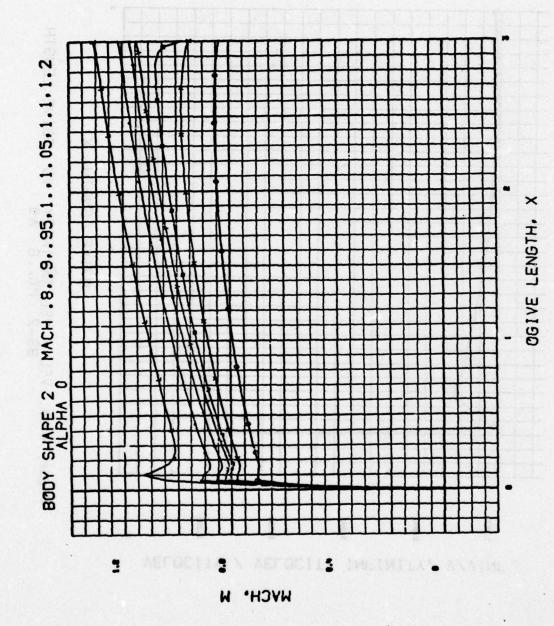


Figure 4-36. MACH VS 061VE LENGTH BS-2 M.8-1.2 A0

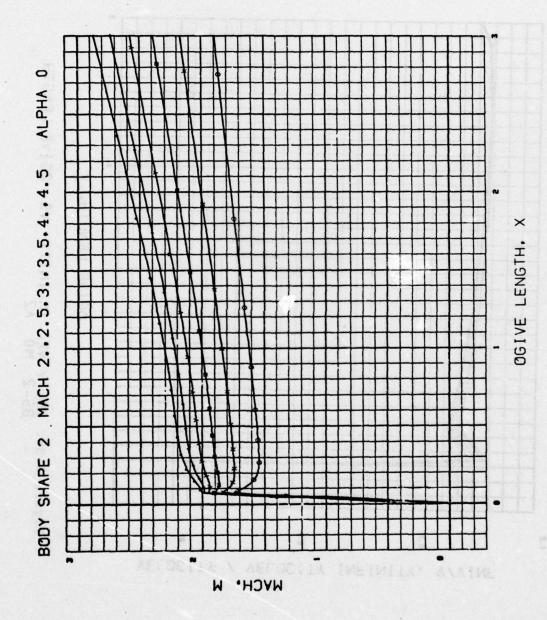


Figure 4-37. MACH VS OGIVE LENGTH BS-2 M2.-4.5 A0

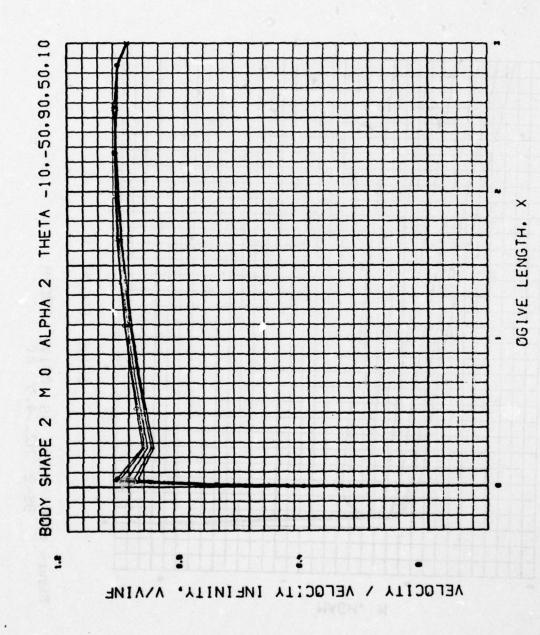


Figure 4-38. VEL / VEL INFINITY VS OGIVE LENGTH BS-2 M0 A2

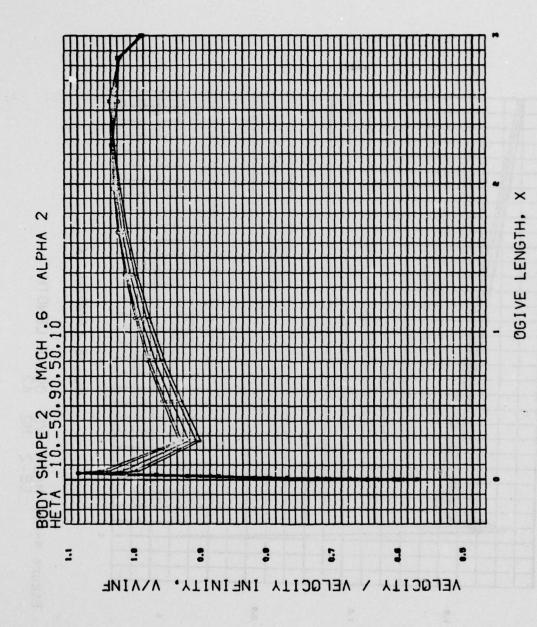


Figure 4-39. VEL / VEL INFINITY VS OGIVE LENGTH BS-2 M.6 A2

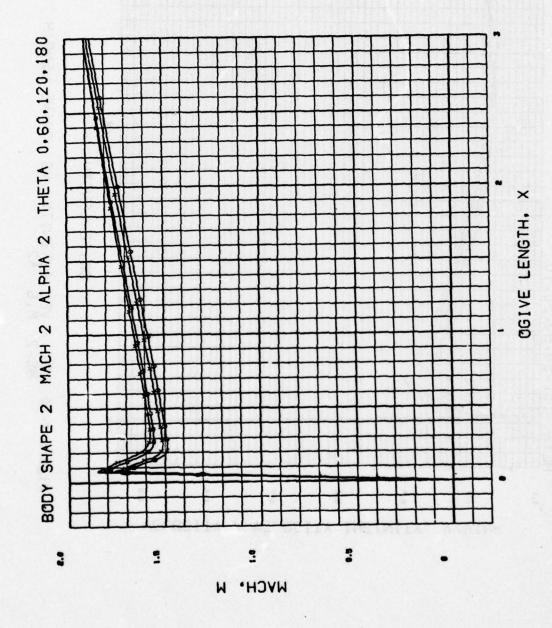
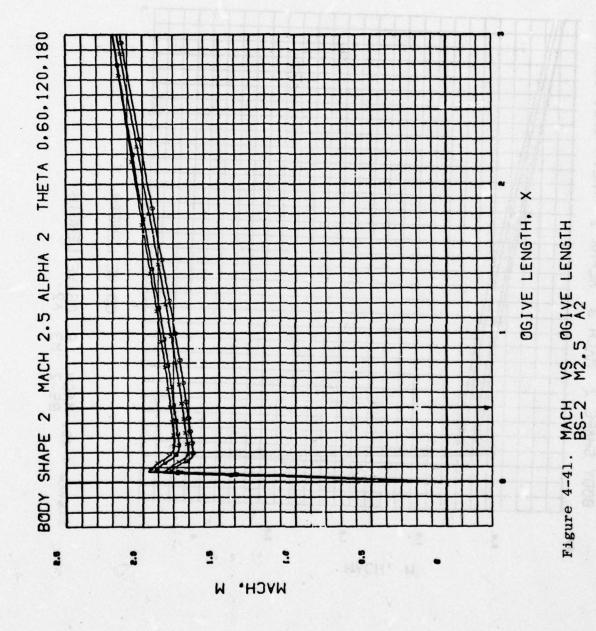
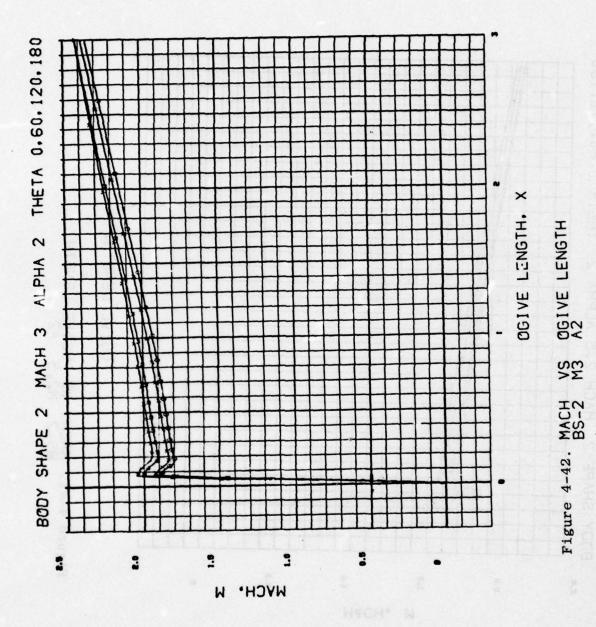


Figure 4-40. MACH VS OGIVE LENGTH BS-2 M2 A2





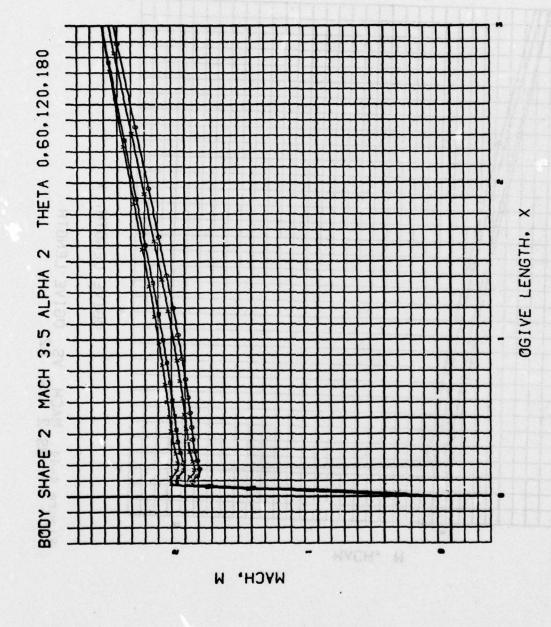
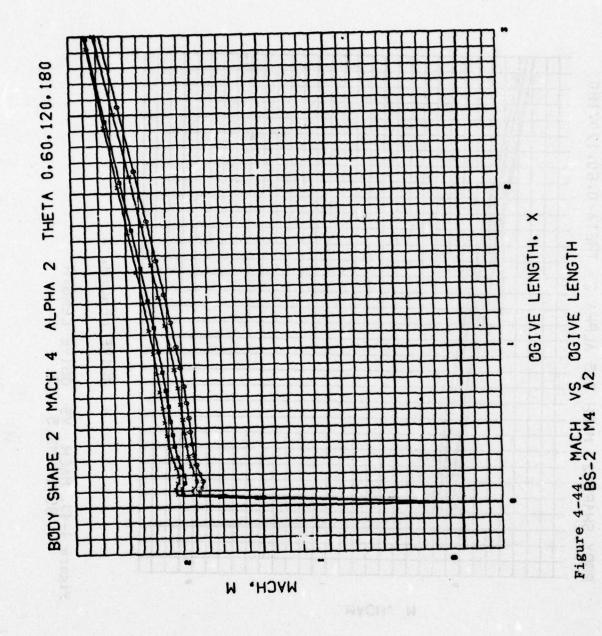


Figure 4-43. MACH VS 06IVE LENGTH BS-2 M3.5 A2



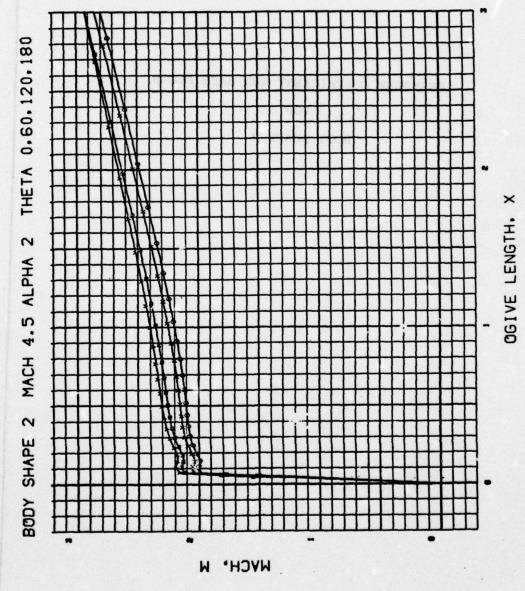
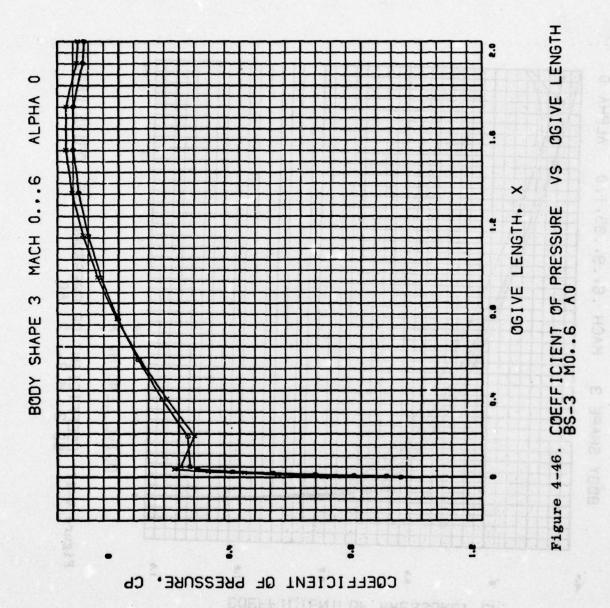


Figure 4-45, MACH VS 06IVE LENGTH BS-2 M4.5 A2

PRESSURE COEFFICIENT AND MACH PLOTS
FOR
BODY SHAPE 3



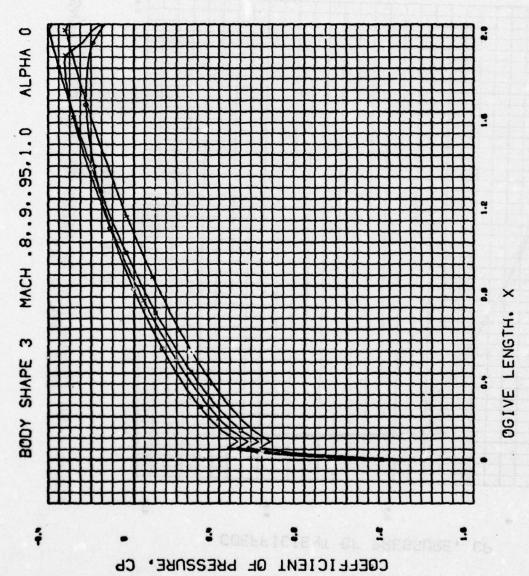


Figure 4-47. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M.8-1.2 A0

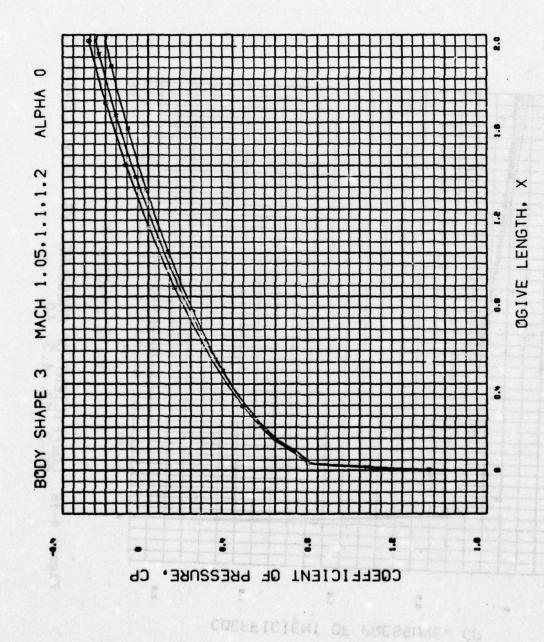
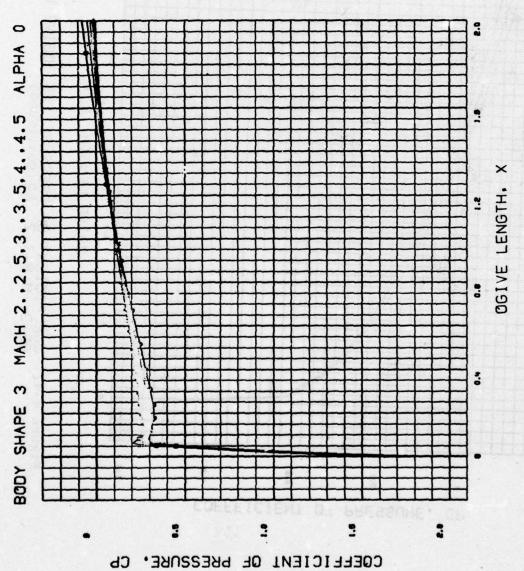


Figure 4-47. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M.8-1.2 A0(Continued)



OGIVE LENGTH Figure 4-48. COEFFICIENT OF PRESSURE VS BS-3 M2.-4.5 A0

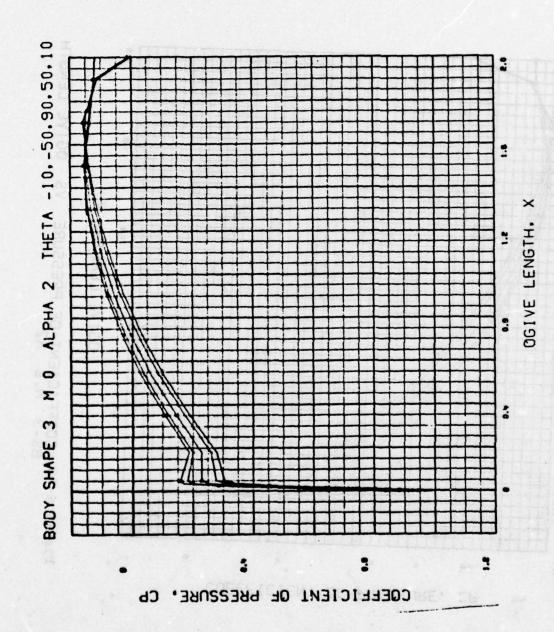


Figure 4-49. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M0 A2

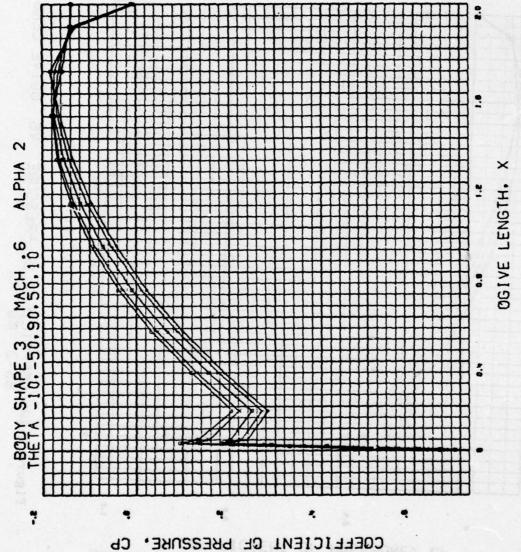


Figure 4-50. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M.6 A2

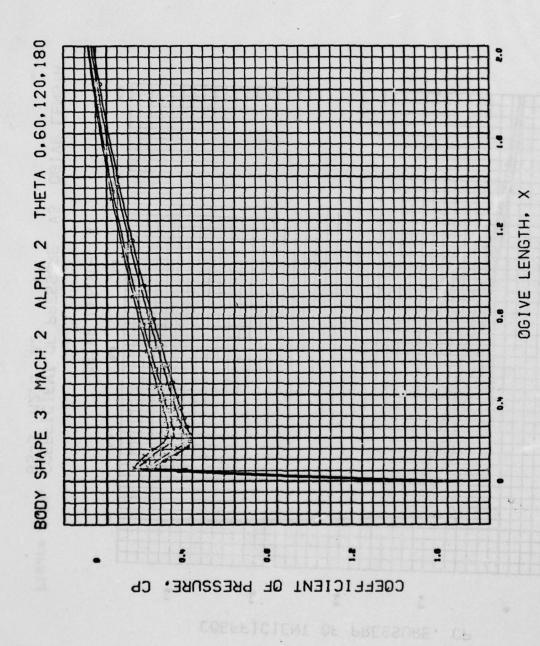


Figure 4-51. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M2 A2

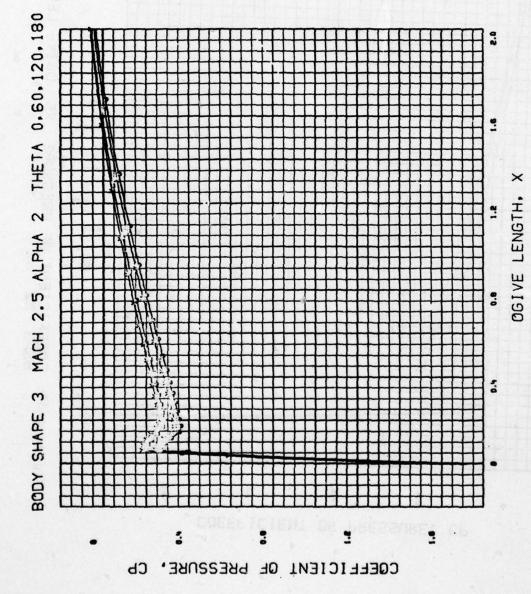
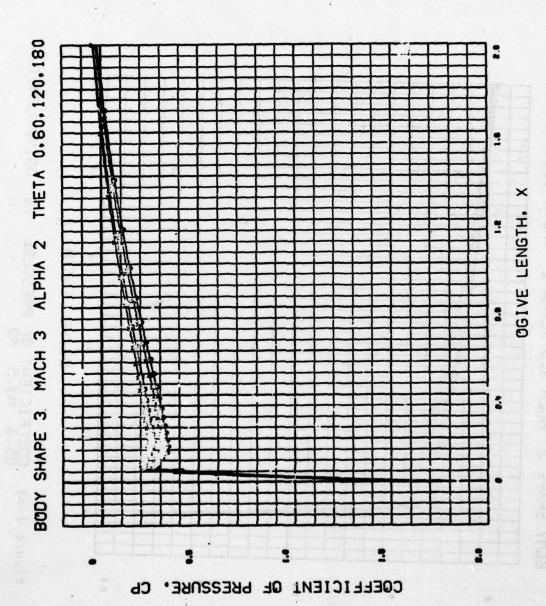
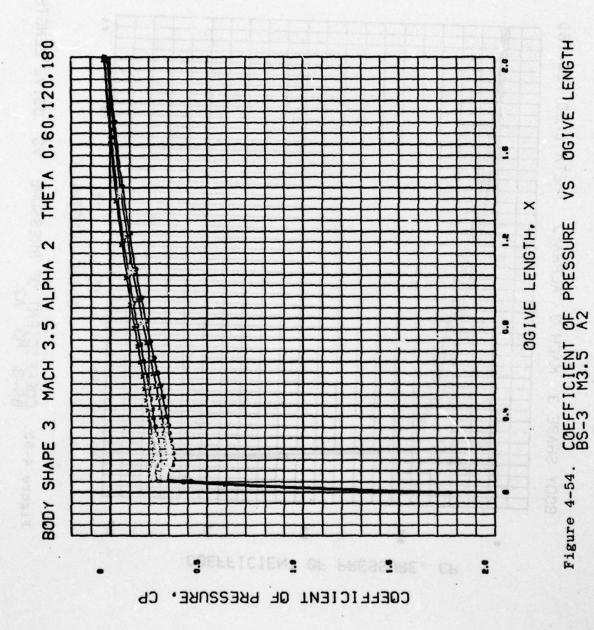


Figure 4-52. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M2.5 A2



VS OGIVE LENGTH COEFFICIENT OF PRESSURE BS-3 M3 A2 Figure 4-53.



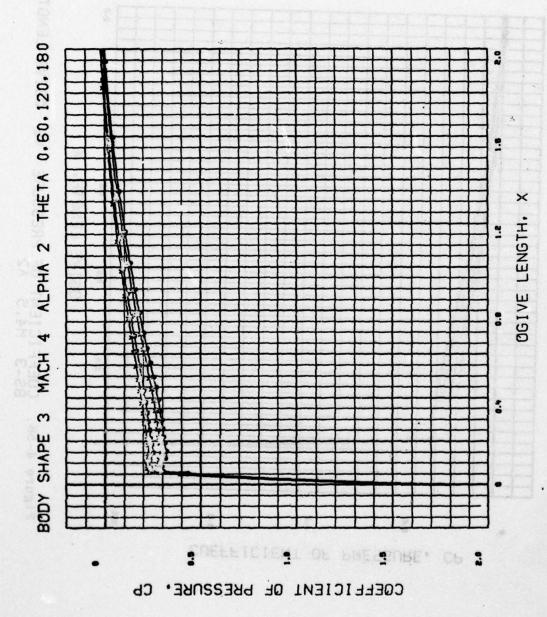
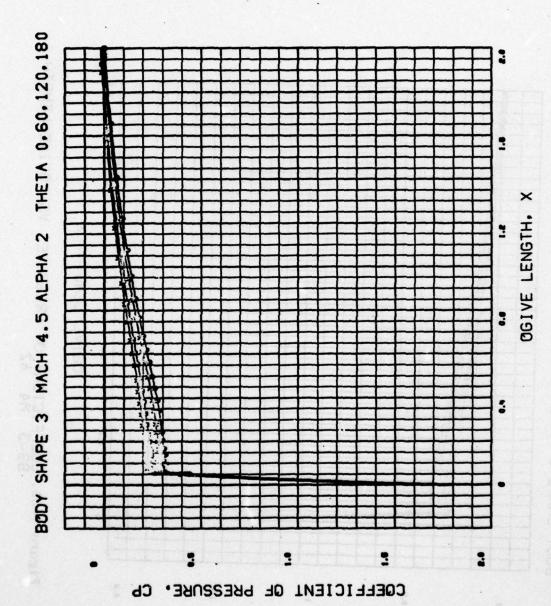
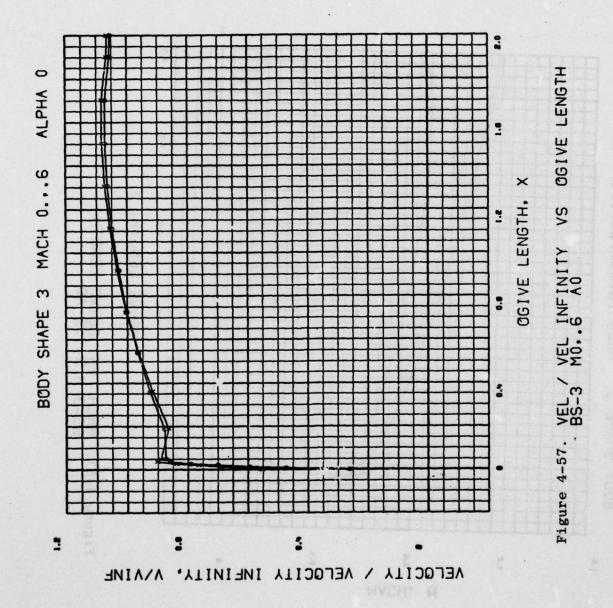


Figure 4-55. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M4 A2



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-3 M4.5 A2 Figure 4-56.



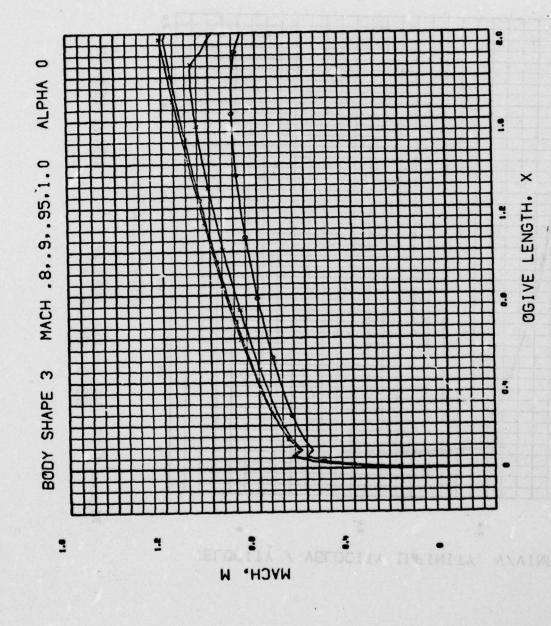


Figure 4-58. MACH VS 0GIVE LENGTH BS-3 M.8-1.2 A0

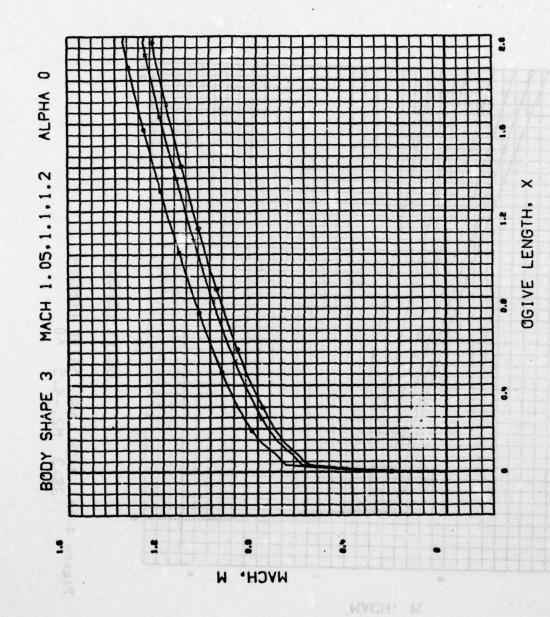


Figure 4-58. MACH VS OGIVE LENGTH BS-3 M.8-1.2 A0 (Continued)

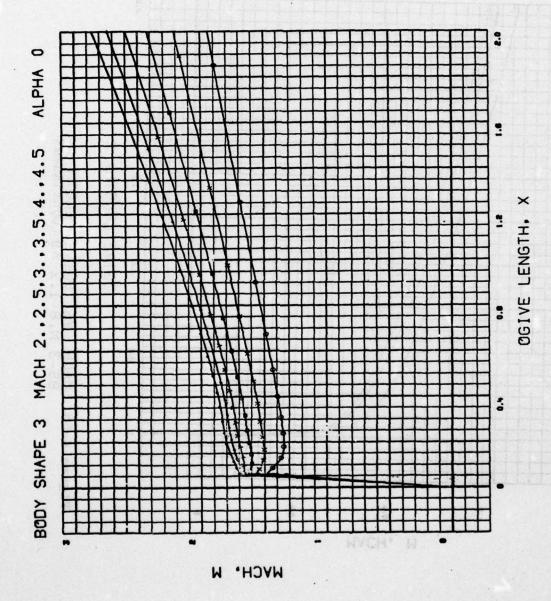


Figure 4-59. MACH VS 061VE LENGTH BS-3 M2.-4.5 A0

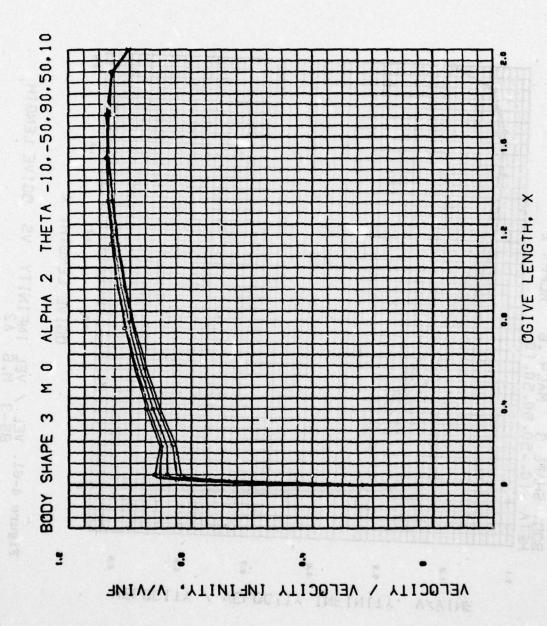


Figure 4-60. VEL / VEL INFINITY VS OGIVE LENGTH BS-3 M0 A2

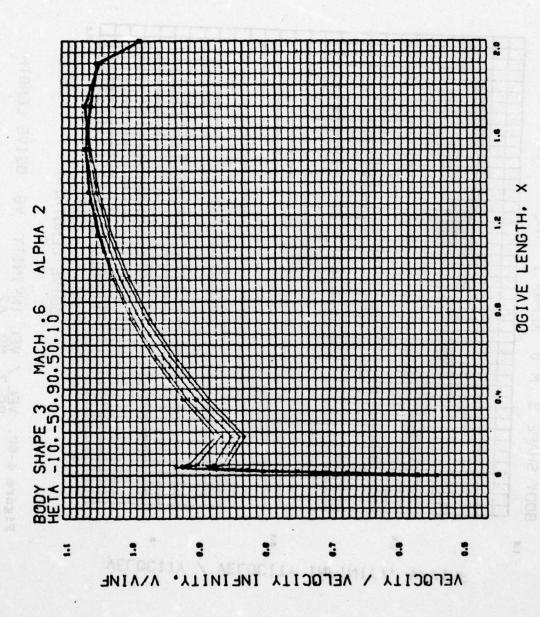
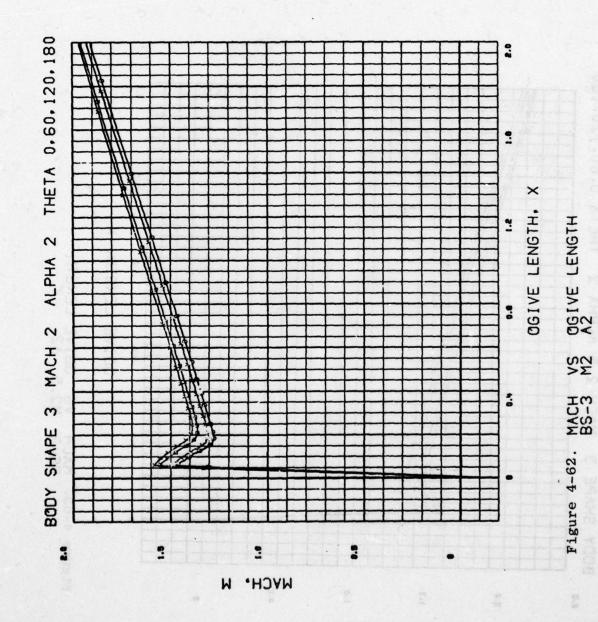


Figure 4-61. VEL / VEL INFINITY VS OGIVE LENGTH BS-3 M.6 A2



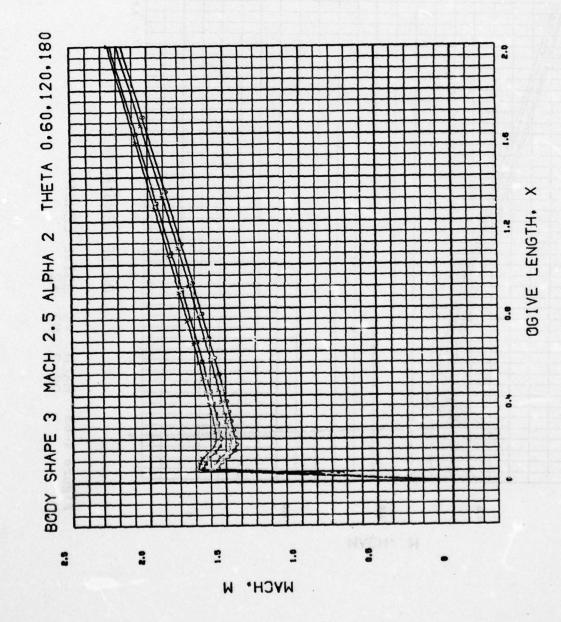
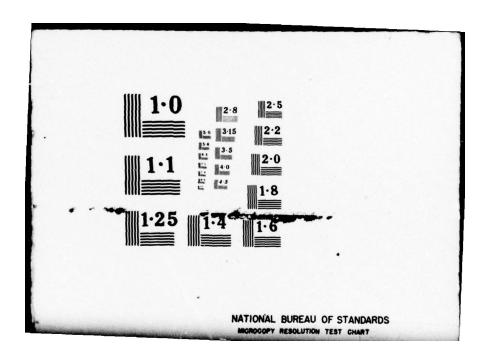


Figure 4-63. MACH VS OGIVE LENGTH BS-3 M2.5 A2

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THEORETICAL ANALYSIS OF THE FLOW FIELD OVER A FAMILY OF OGIVE B--ETC(U)
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NL AD-A048 477 UNCLASSIFIED 2 of 5 AD A048477 W/1



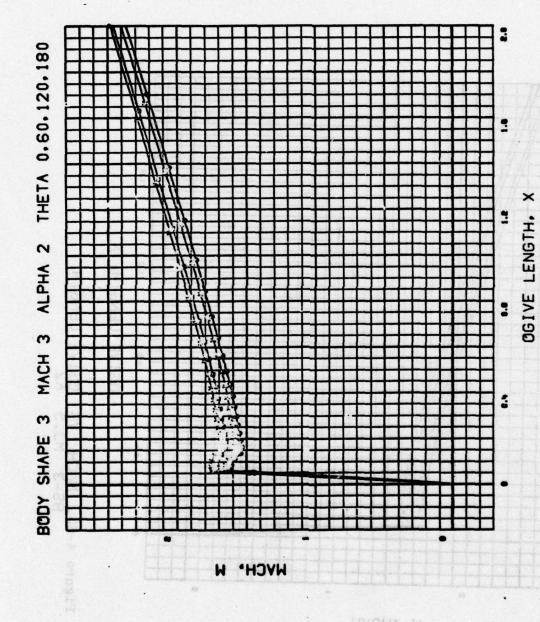


Figure 4-64. MAC'4 VS 06IVE LENGTH BS-3 M3 A2

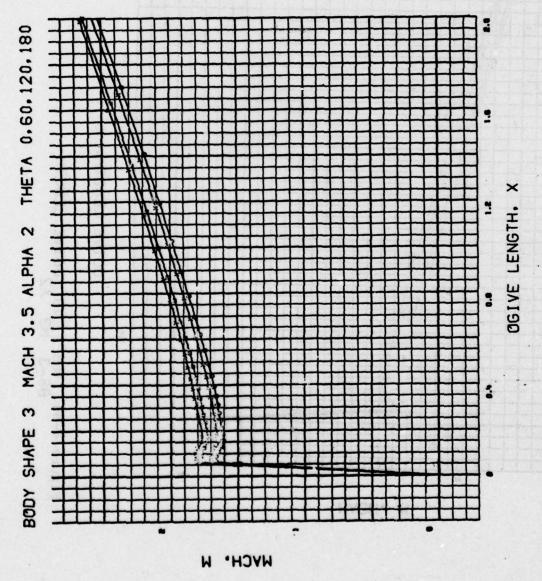


Figure 4-65. MACH VS 06IVE LENGTH 85-3 M3.5 A2

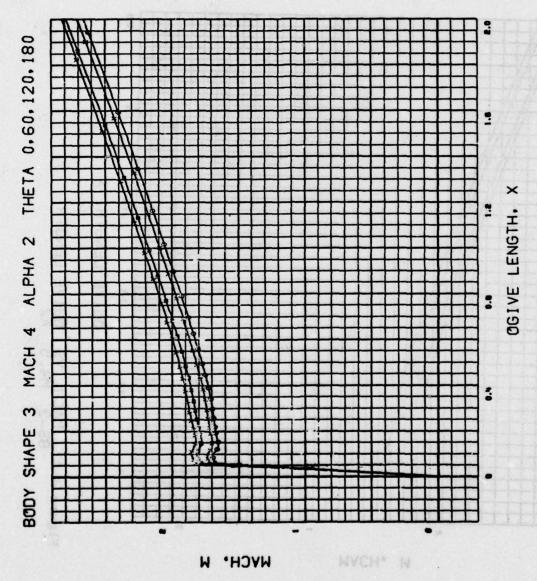
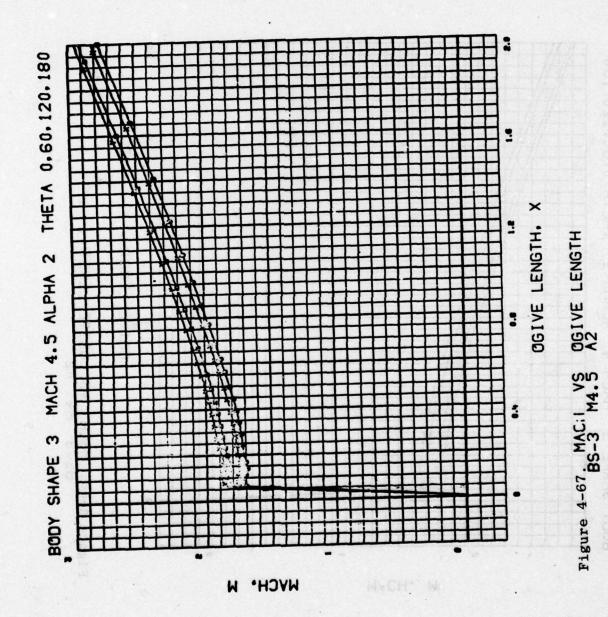


Figure 4-66. MACH VS OGIVE LENGTH BS-3 M4 A2

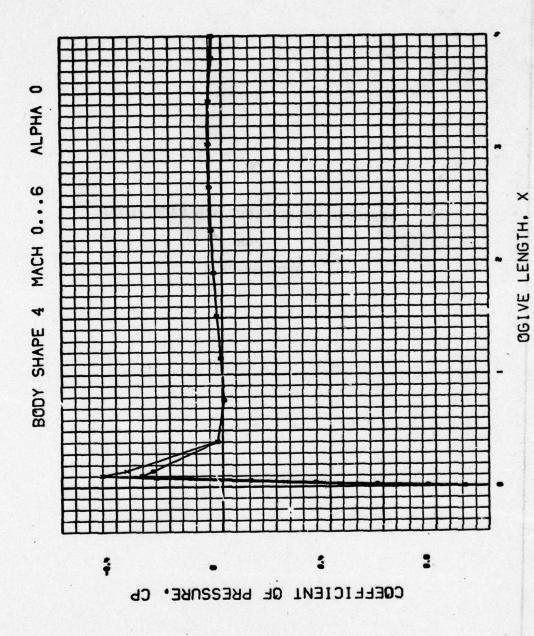


PRESSURE COEFFICIENT AND MACH PLOTS

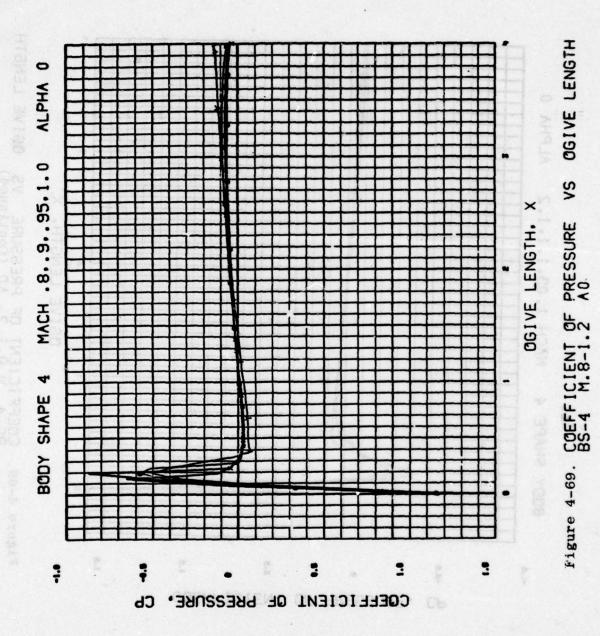
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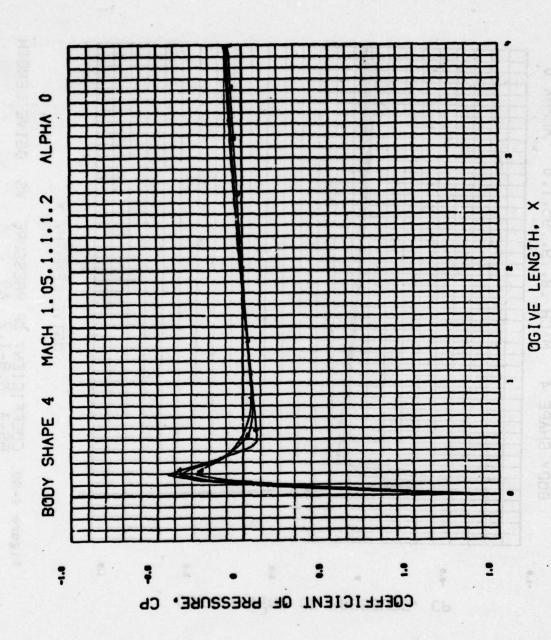
BODY SHAPE 4

CORFFICIENT OF PRESSURE. (



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-4 MO..6 A0 Figure 4-68.





COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-4 M.8-1.2 AO (Continued)

Figure 4-69.

92

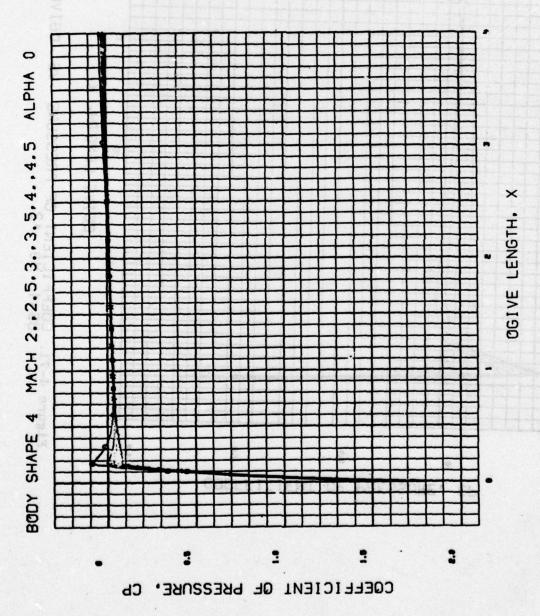


Figure 4-70. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-4 M2.-4.5 A0

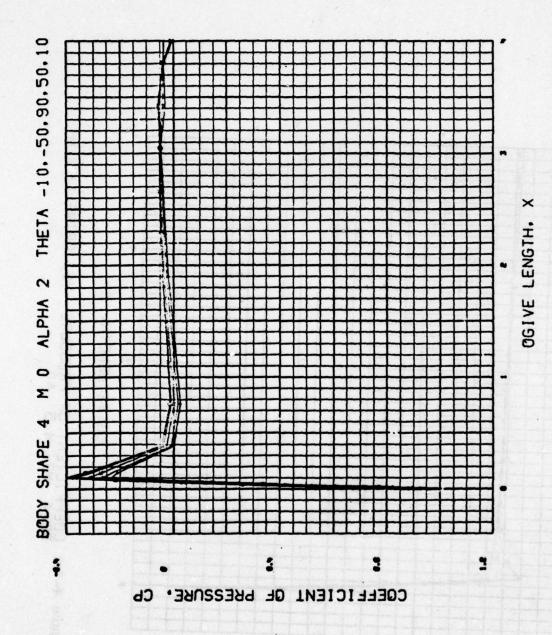
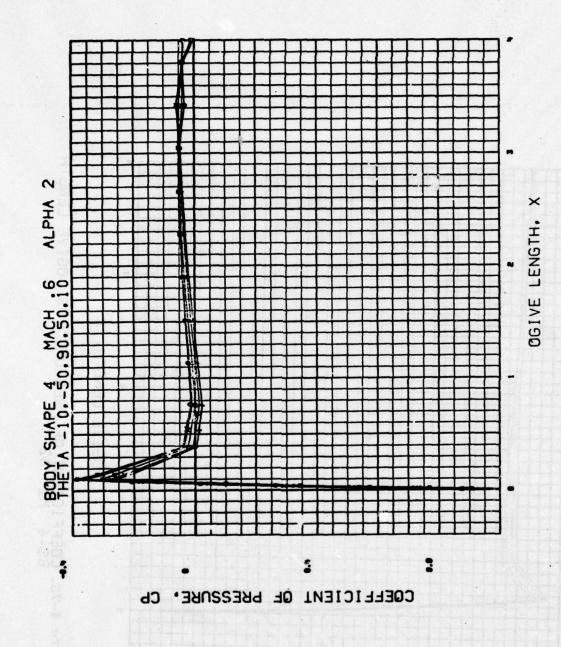
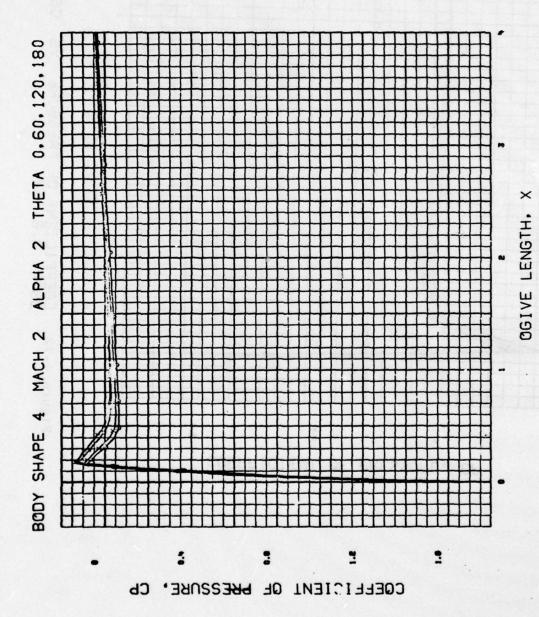


Figure 4-71. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-4 MO A2



OGIVE LENGTH ۸S COEFFICIENT OF PRESSURE BS-4 M.6 A2 Figure 4-72.



OGIVE LENGTH Figure 4-73. COEFFICIENT OF PRESSURE VS BS-4 M2 A2

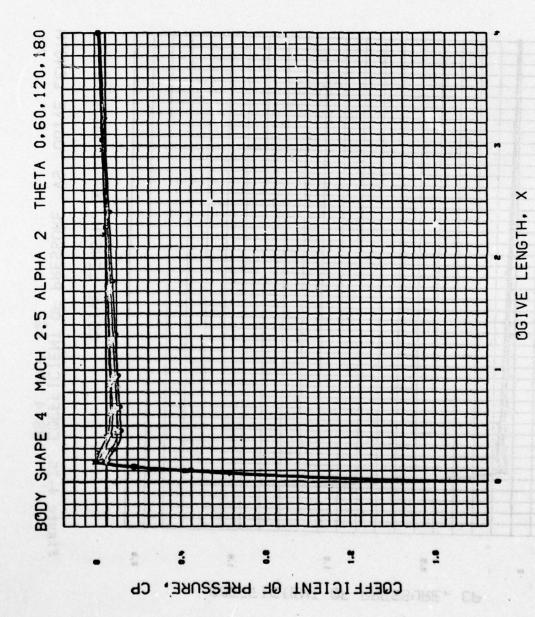
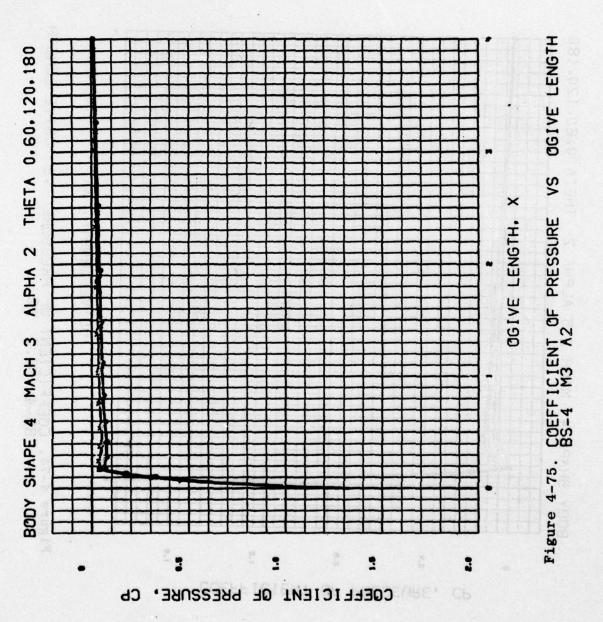
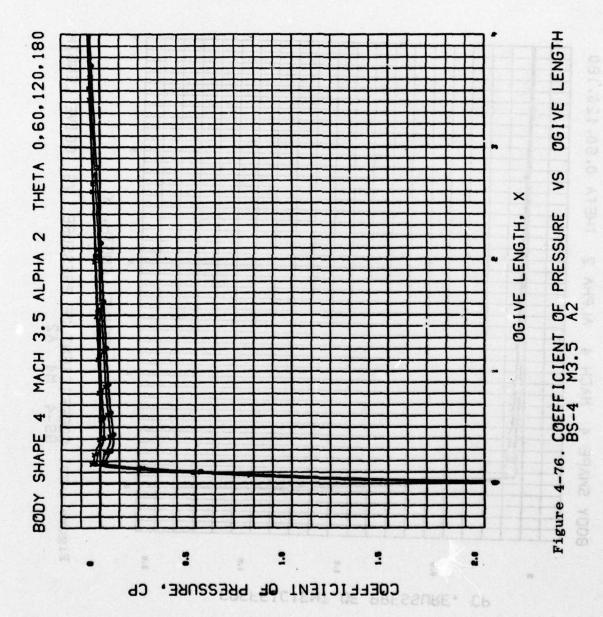
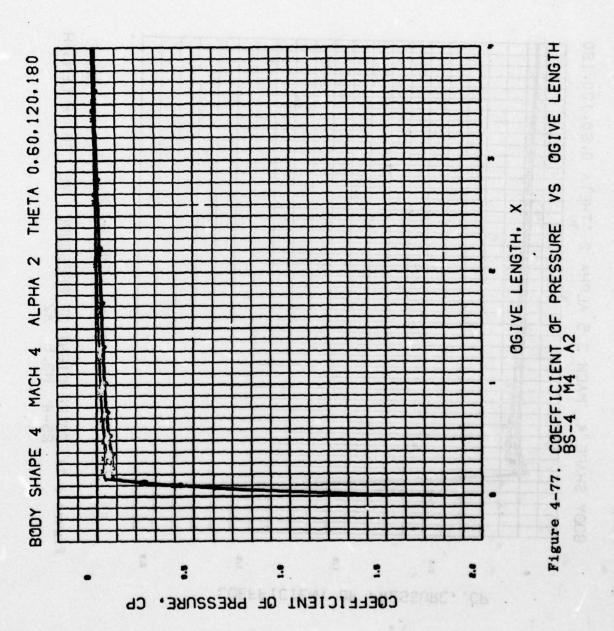


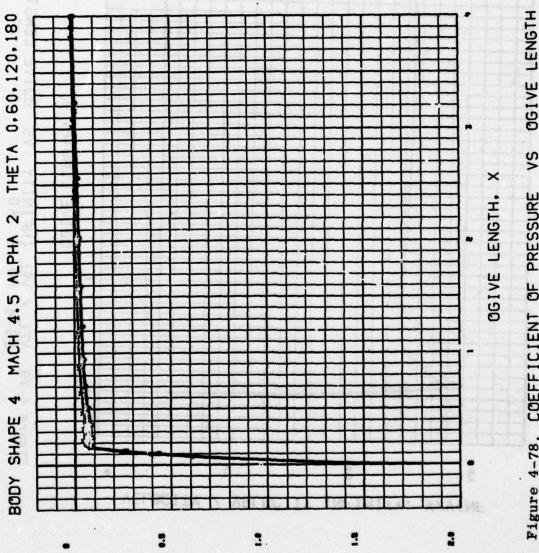
Figure 4-74. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-4 M2.5 A2







COEFFICIENT OF PRESSURE.



OGIVE LENGTH Figure 4-78. COEFFICIENT OF PRESSURE VS BS-4 M4.5 A2

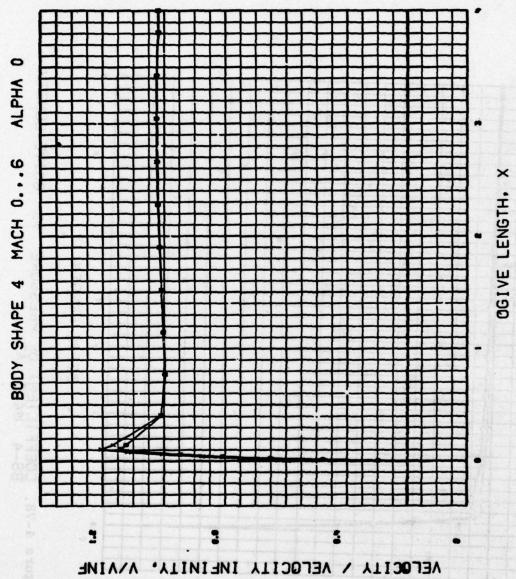
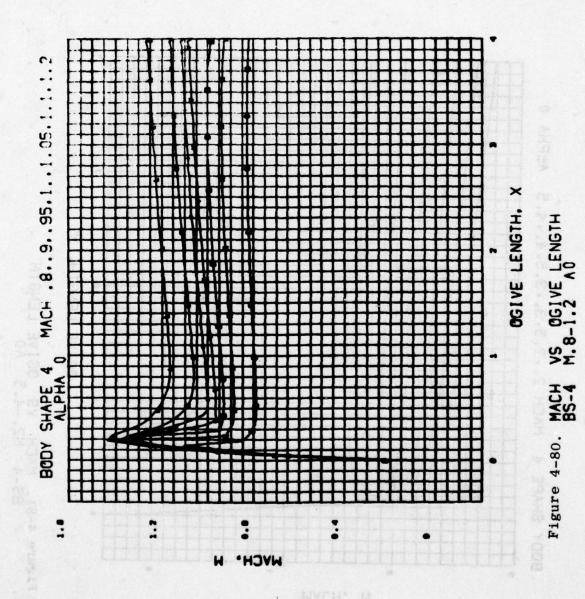


Figure 4-79. VEL / VEL INFINITY VS OGIVE LENGTH BS-4 M0.6 A0



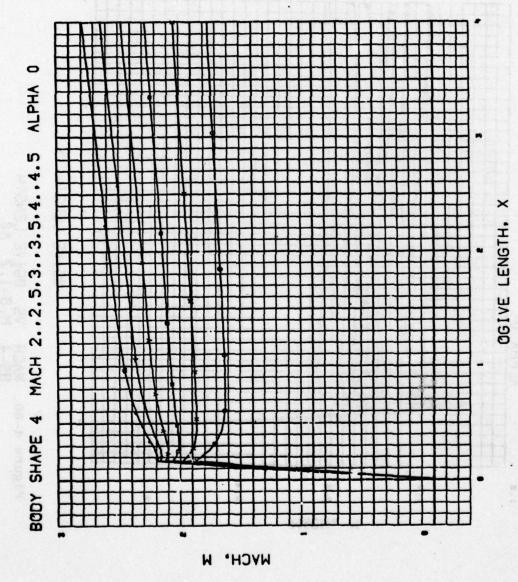


Figure 4-81. MACH VS OGIVE LENGTH BS-4 M2.-4.5 A0

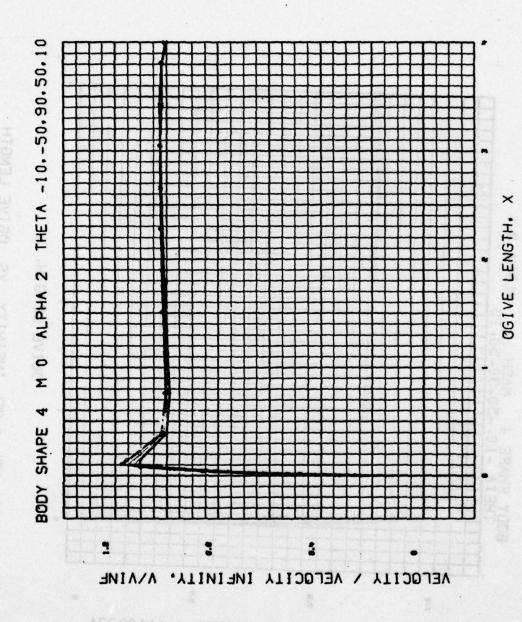


Figure 4-82. VEL / VEL INFINITY VS OGIVE LENGTH

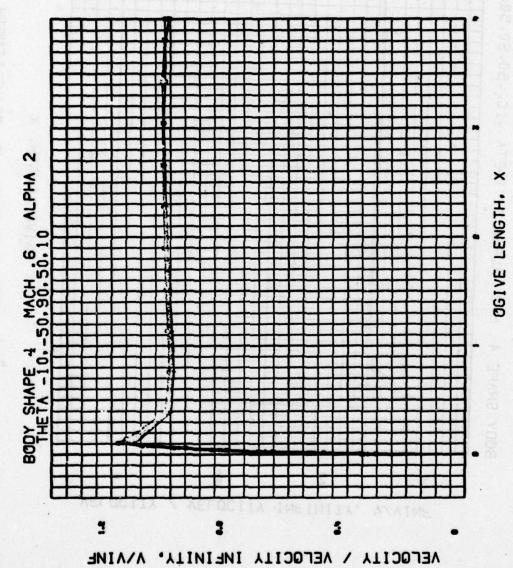
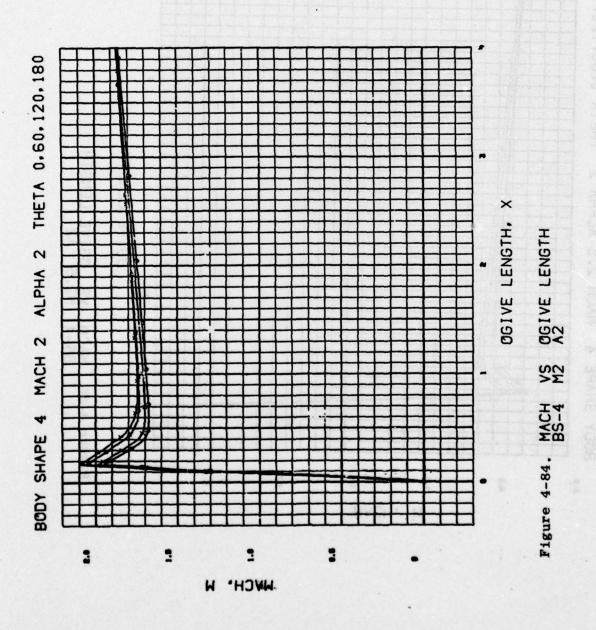
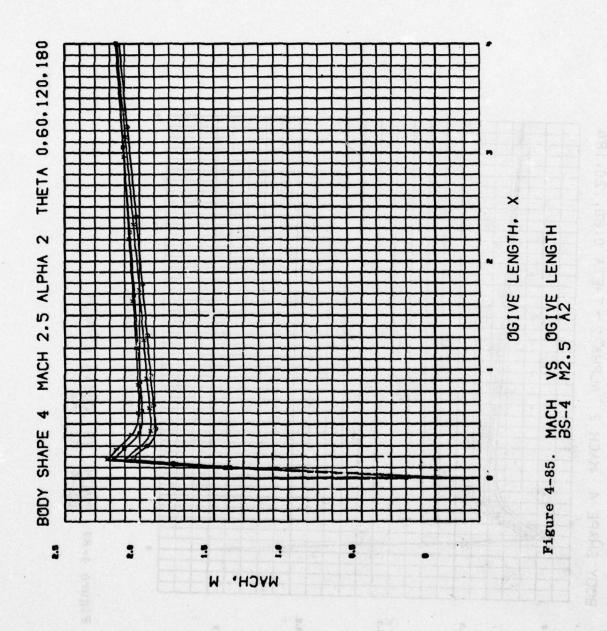


Figure 4-83. VEL / VEL INFINITY VS OGIVE LENGTH BS-4 M.6 A2





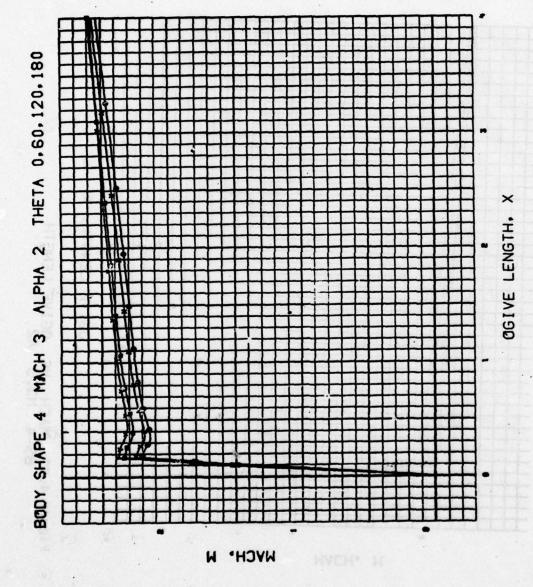


Figure 4-86. MACH VS OGIVE LENGTH BS-4 M3 A2

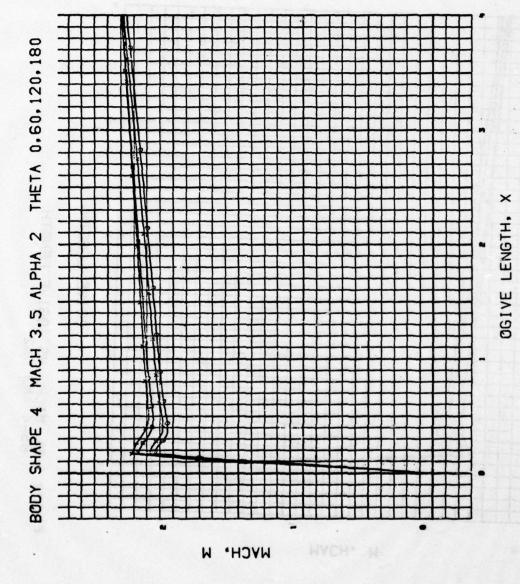


Figure 4-87. MACH VS @GIVE LENGTH BS-4 M3.5 A2

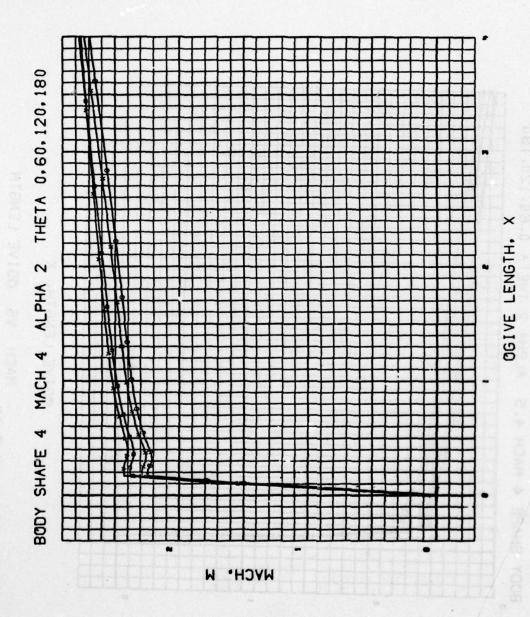


Figure 4-85. MACH VS 06IVE LENGTH BS-4 M4 A2

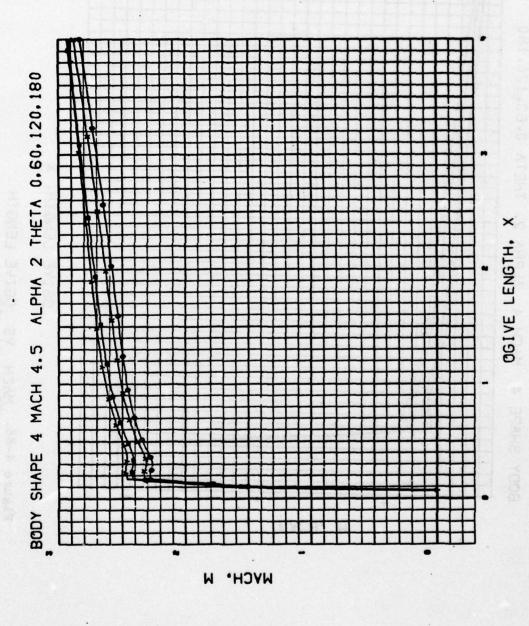


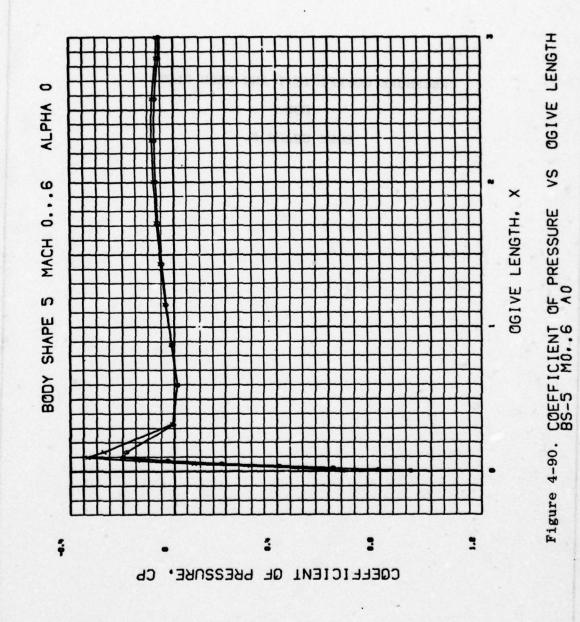
Figure 4-89. BS-4 M4.5 A2

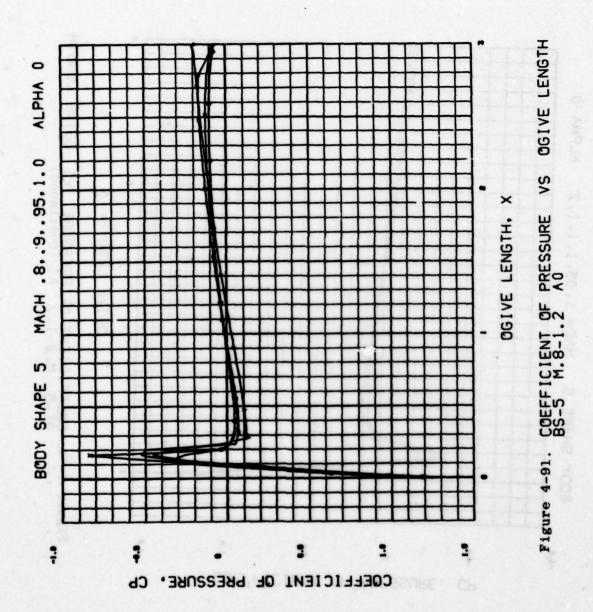
PRESSURE COEFFICIENT AND MACH PLOTS

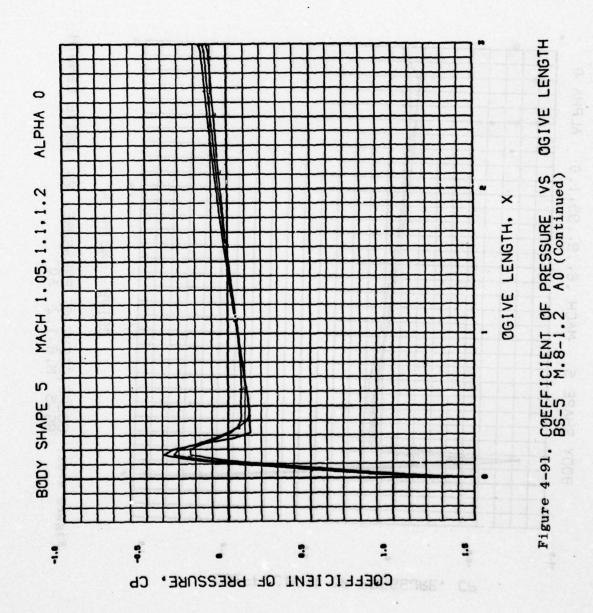
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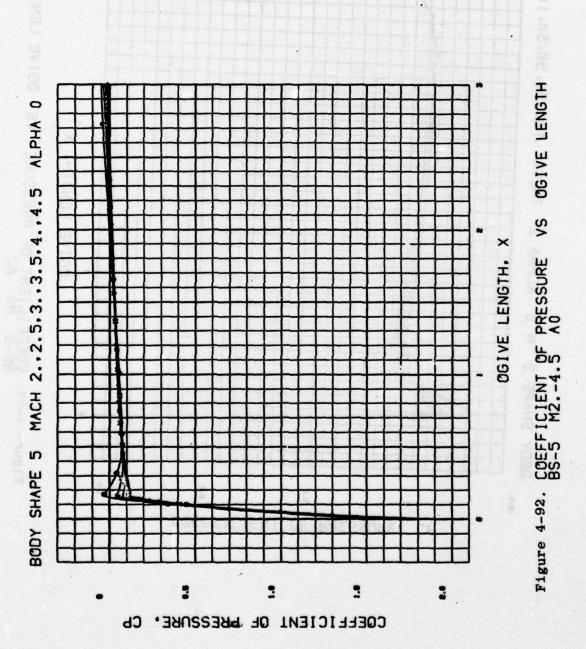
BODY SHAPE 5











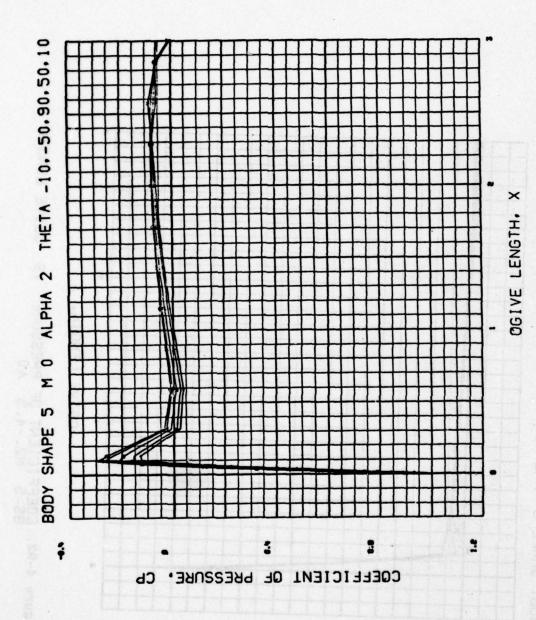
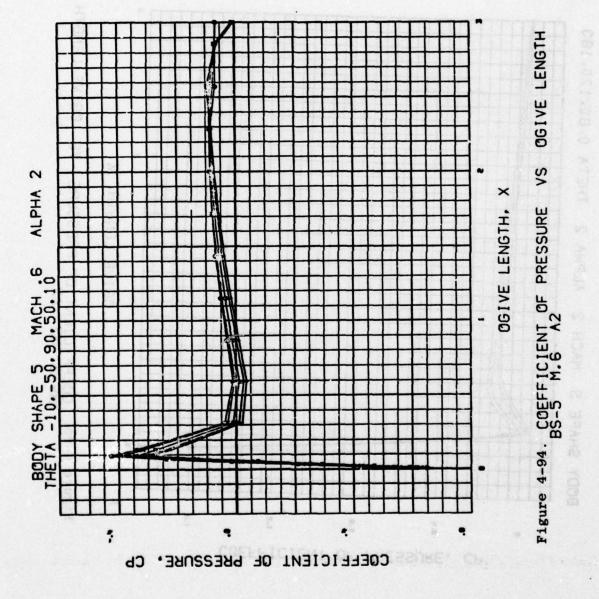
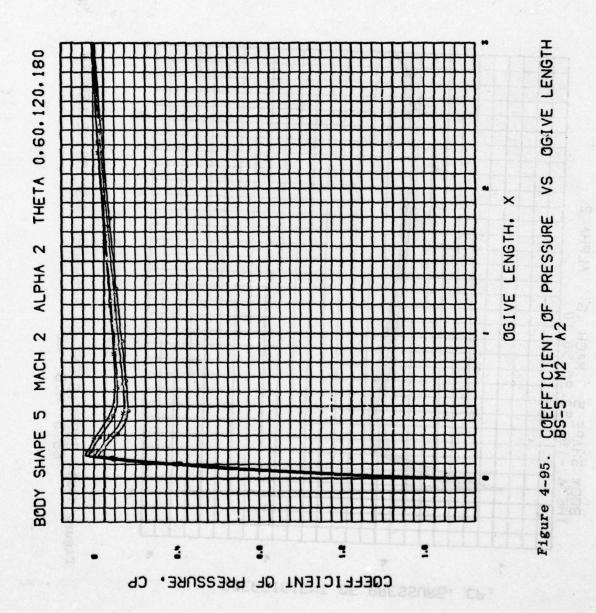
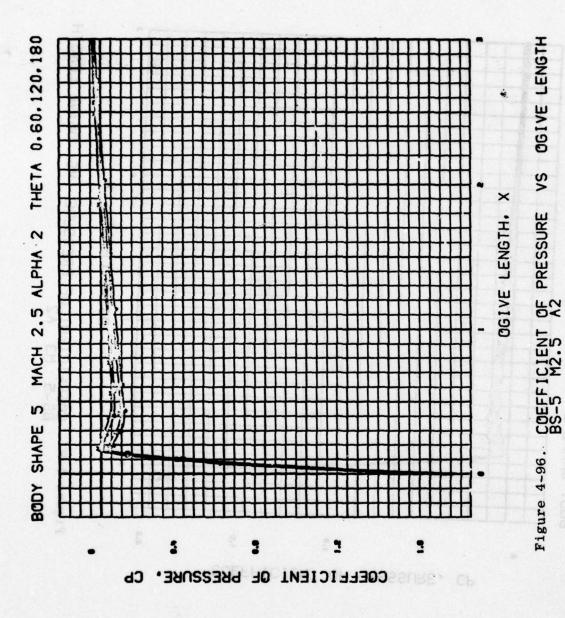
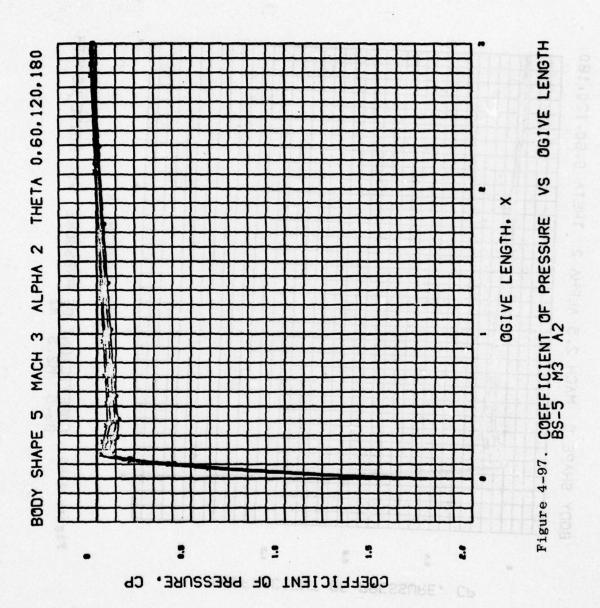


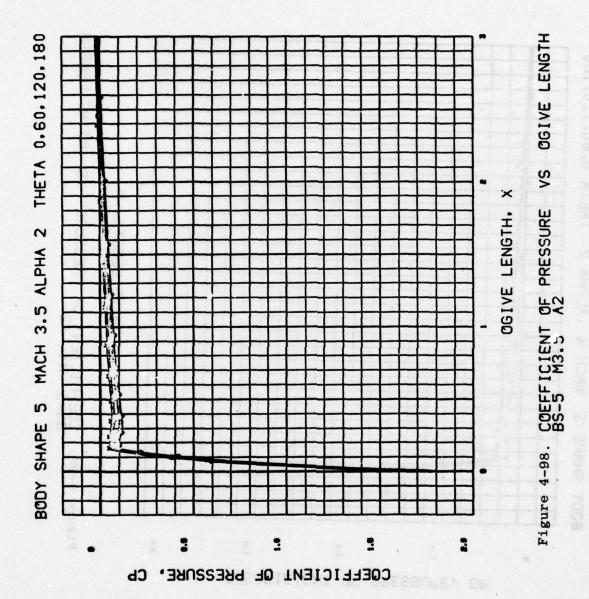
Figure 4-93. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-5 M0 A2

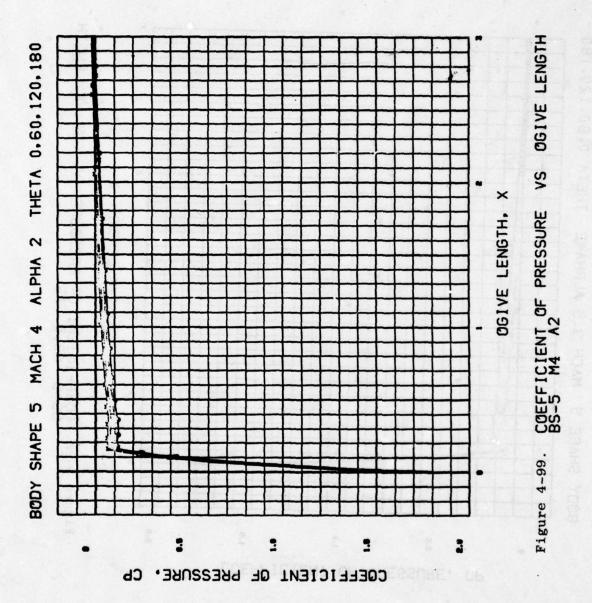


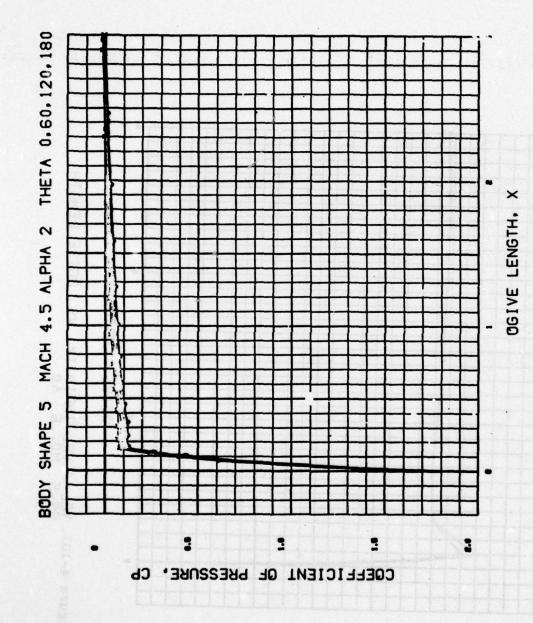












OGIVE LENGTH Figure 4-100. COEFFICIENT OF PRESSURE VS BS-5 M4.5 A2

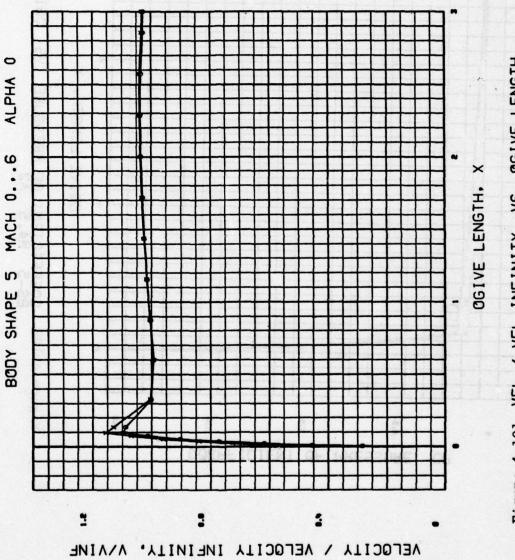
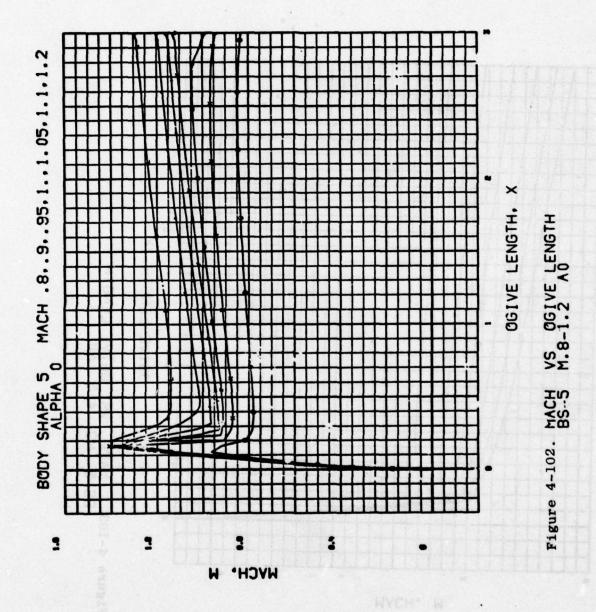
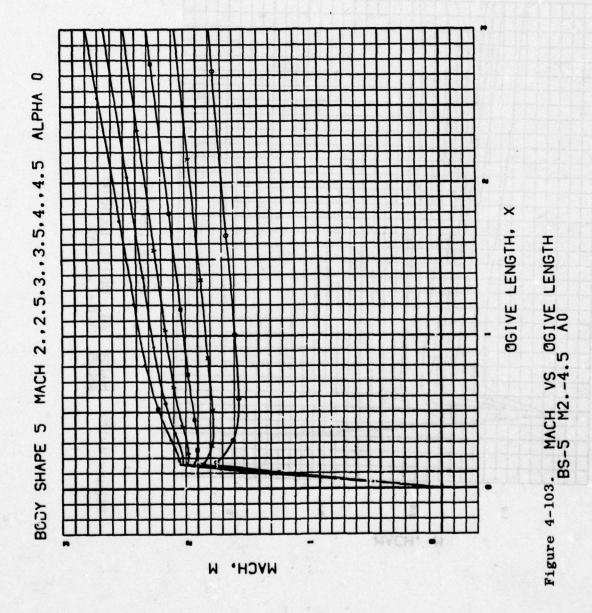


Figure 4-101. VEL / VEL INFINITY VS OGIVE LENGTH BS-5 M0.6 A0





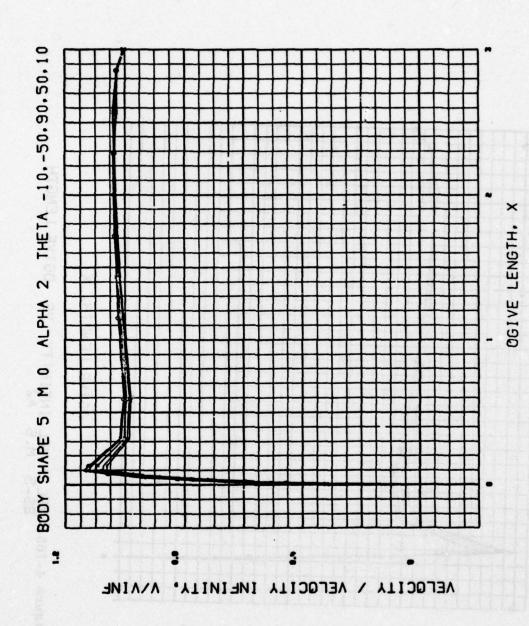


Figure 4-104. VEL / VEL INFINITY VS OGIVE LENGTH BS-5 M0 A2

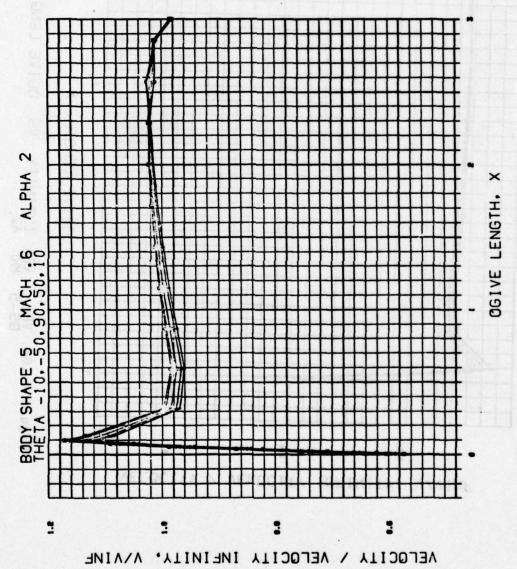
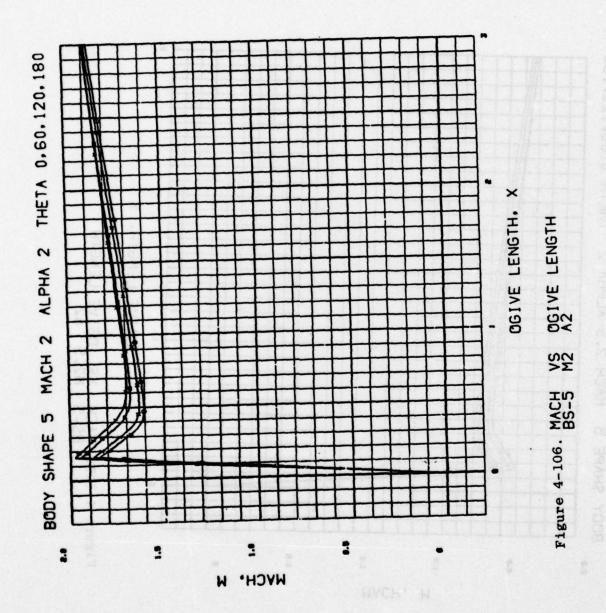
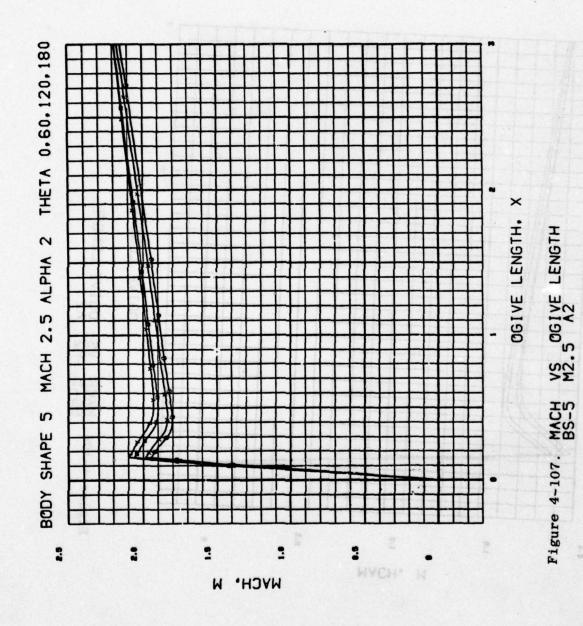


Figure 4-105. VEL / VEL INFINITY VS OGIVE LENGTH BS-5 M.6 A2





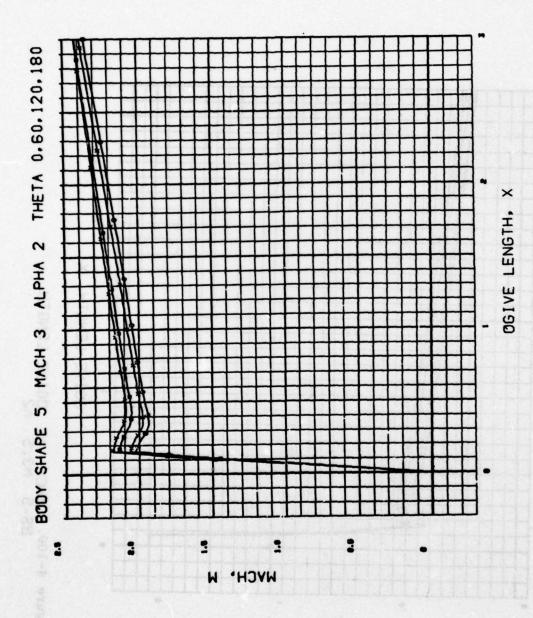


Figure 4-108. MACH VS 0GIVE LENGTH BS-5 M3 A2

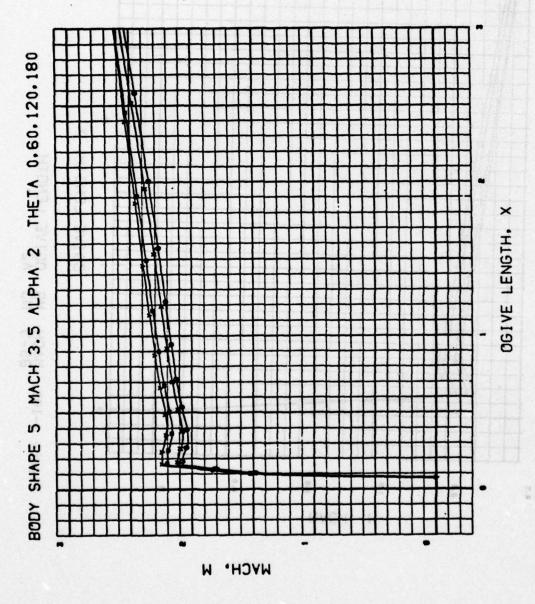


Figure 4-109. MACH VS OGIVE LENGTH BS-5 M3.5 A2

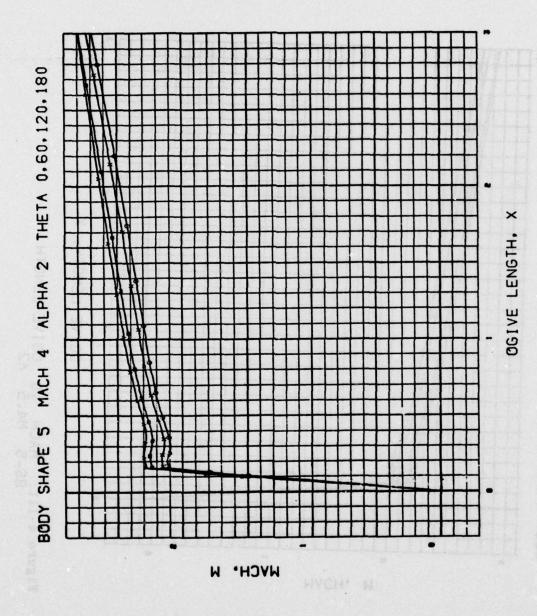


Figure 4-110. MACH VS OGIVE LENGTH BS-5 M4 A2

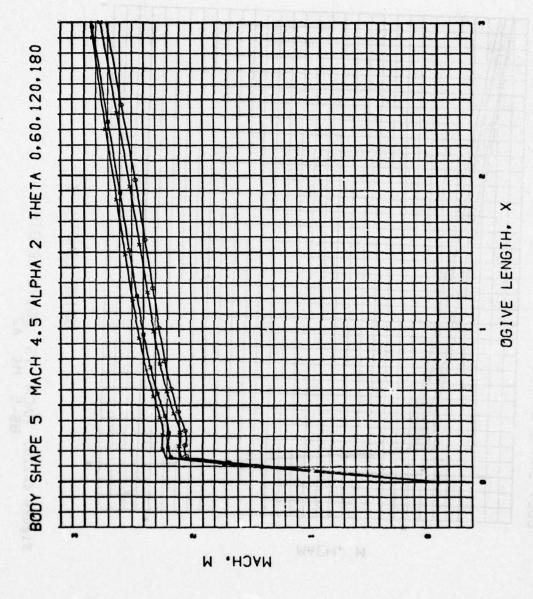


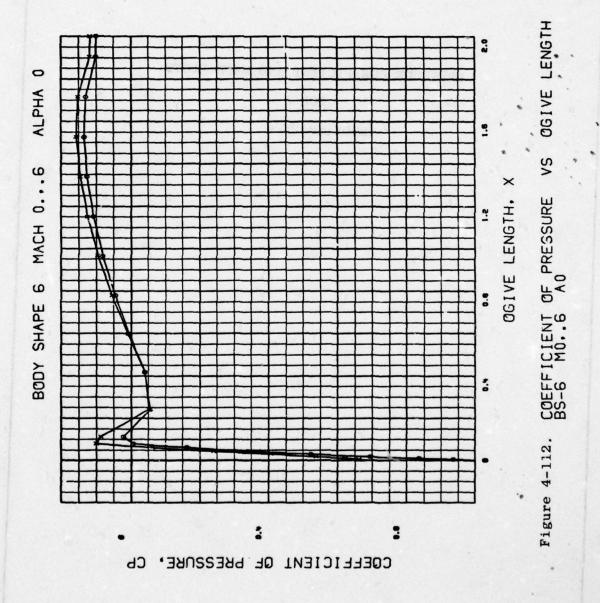
Figure 4-111, MACH VS 061VE LENGTH BS-5 M4.5 A2

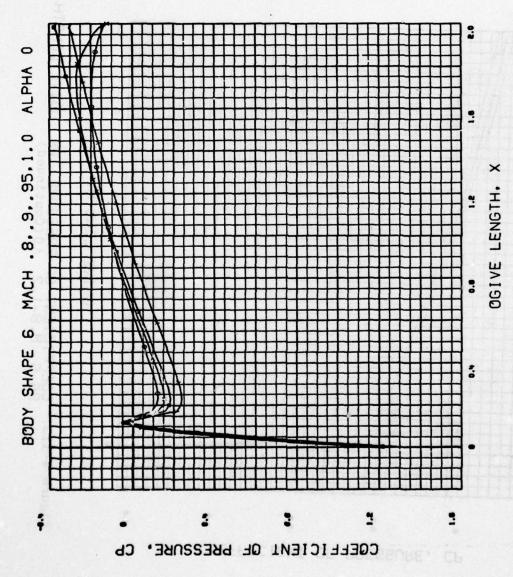
PRESSURE COEFFICIENT AND MACH PLOTS

FOR

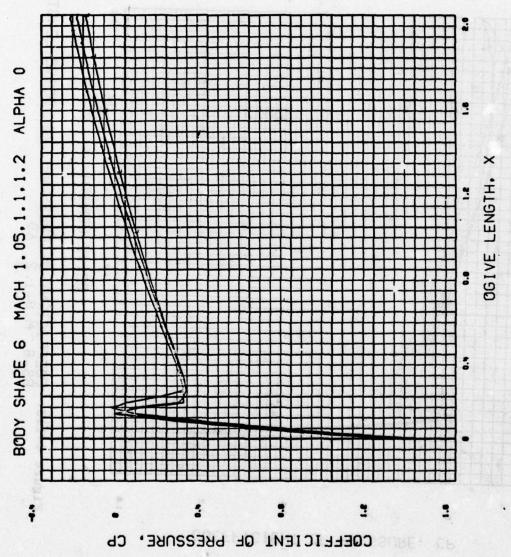
BODY SHAPE 6







COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-6 M.8-1.2 A0 Figure 4-113.



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-6 M.8-1.2 A0(Continued) Figure 4-113.

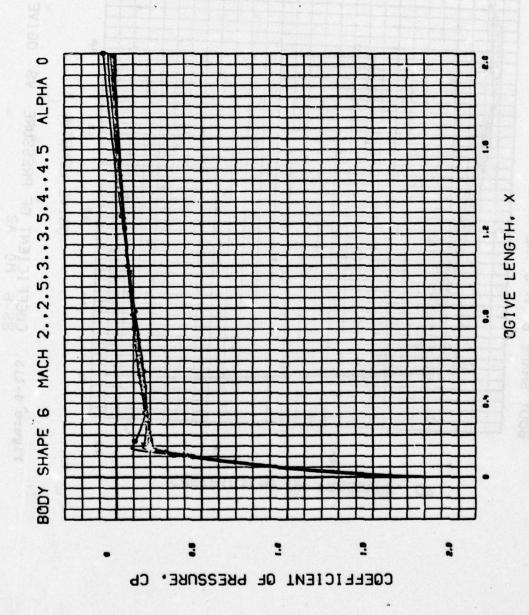


Figure 4-114. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-6 M2.-4.5 A0

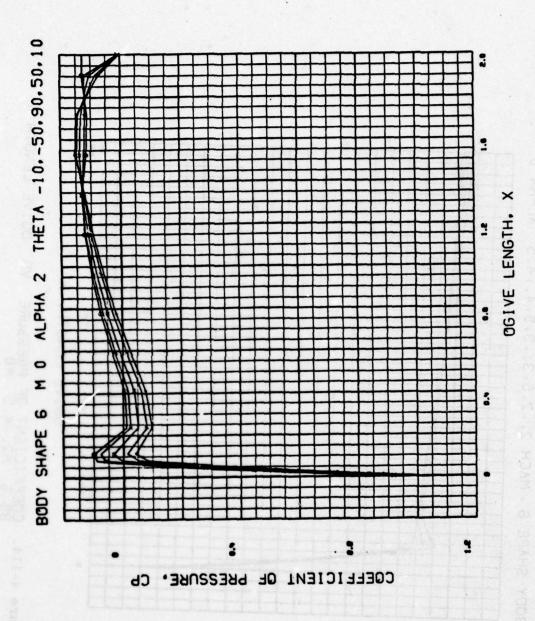
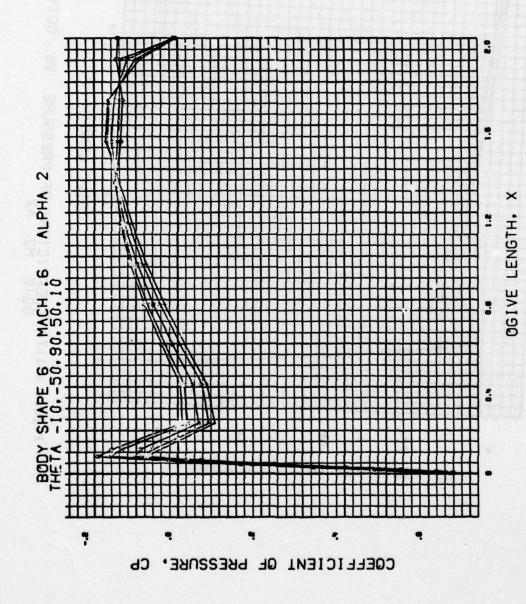
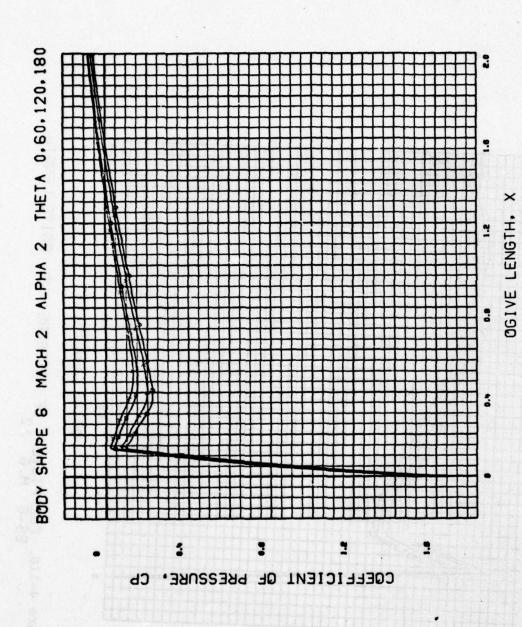


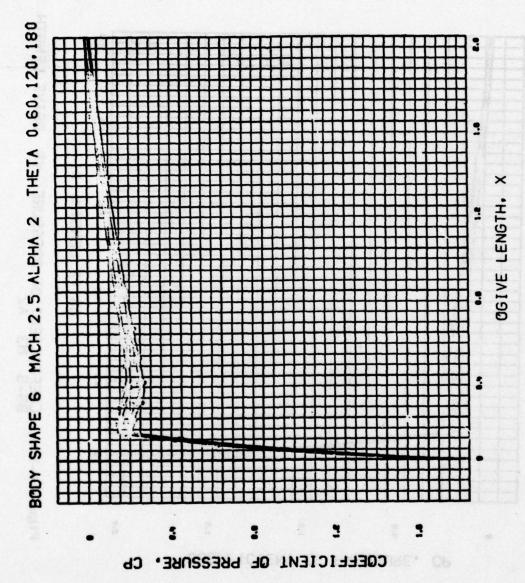
Figure 4-115. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-6 M0 A2



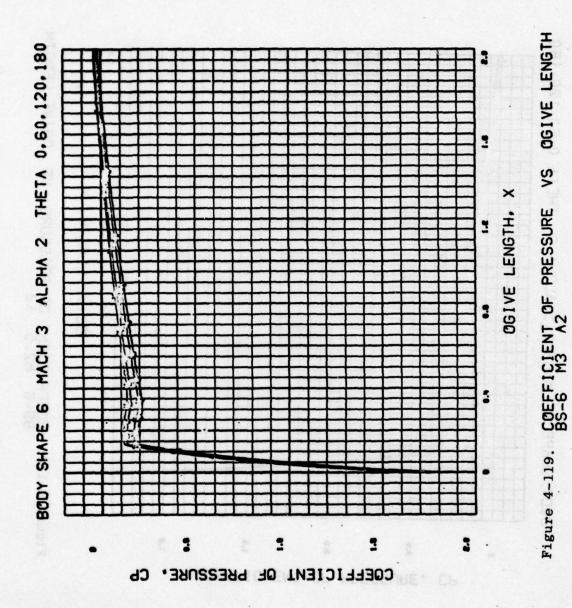
OGIVE LENGTH Figure 4-116. COEFFICIENT OF PRESSURE VS BS-6 M.6 A2



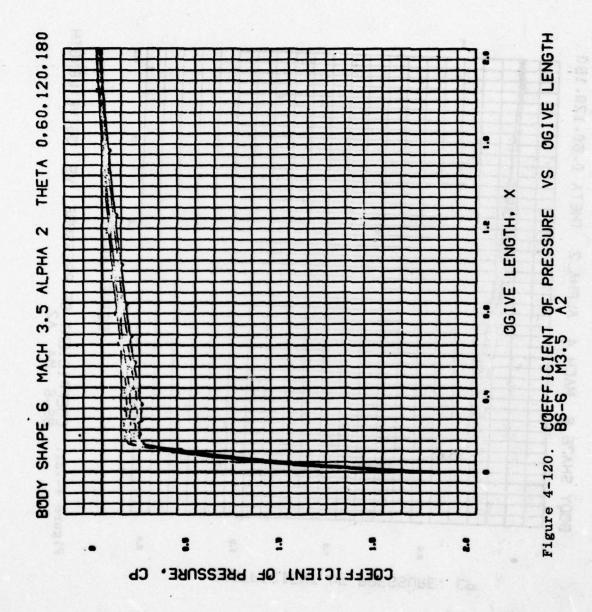
OGIVE LENGTH Figure 4-117. COEFFICIENT OF PRESSURE VS BS-6 M2 A2

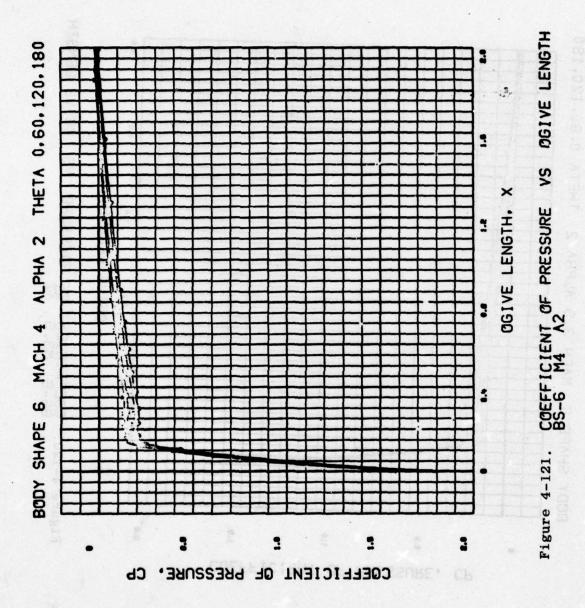


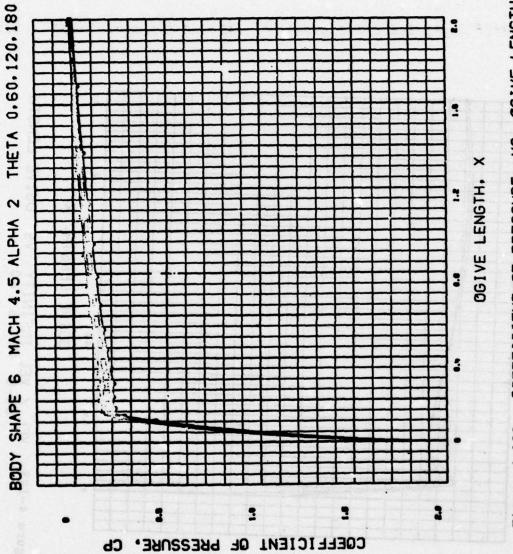
COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-6 M2.5 A2 Figure 4-118.



- 146







COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-6 M4.5 A2 Figure 4-122.

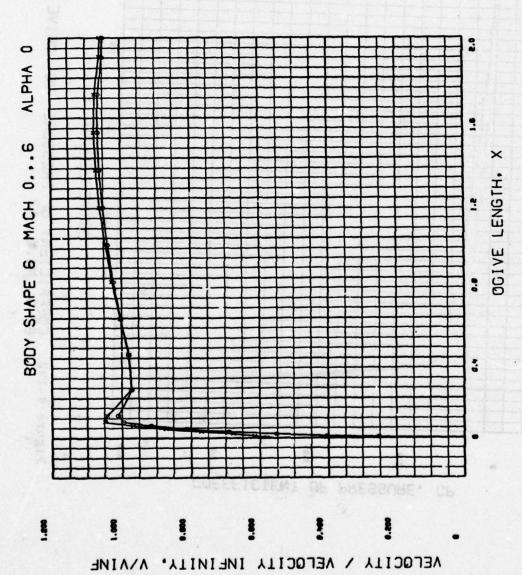
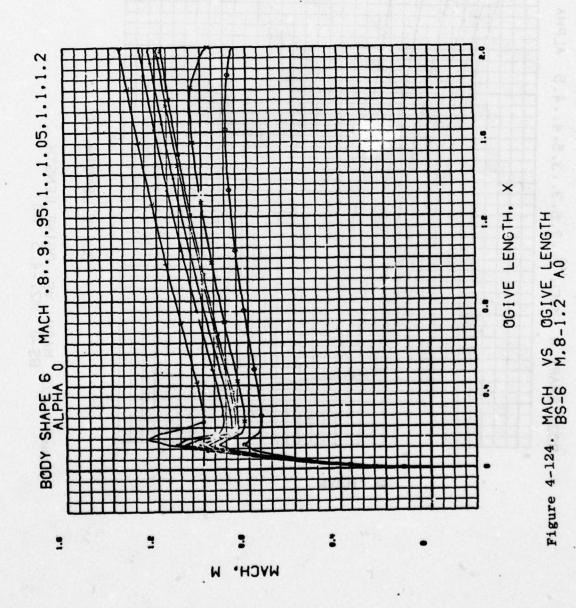


Figure 4-123. VEL / VEL INFINITY VS OGIVE LENGTH BS-6 M0..6 A0



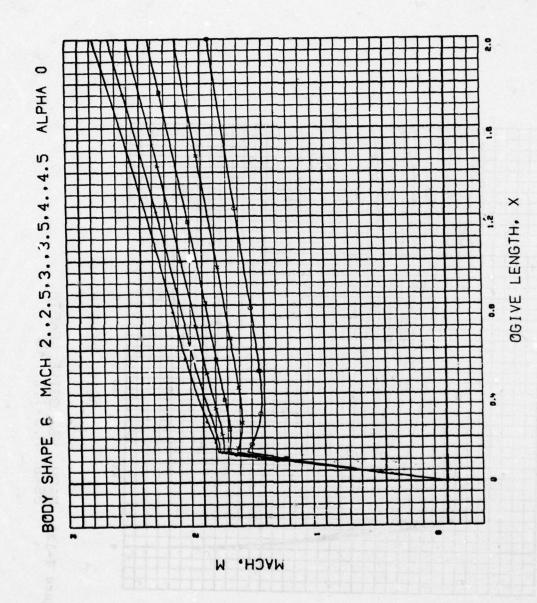


Figure 4-125. MACH VS 0GIVE LENGTH BS-6 M2.-4.5 A0

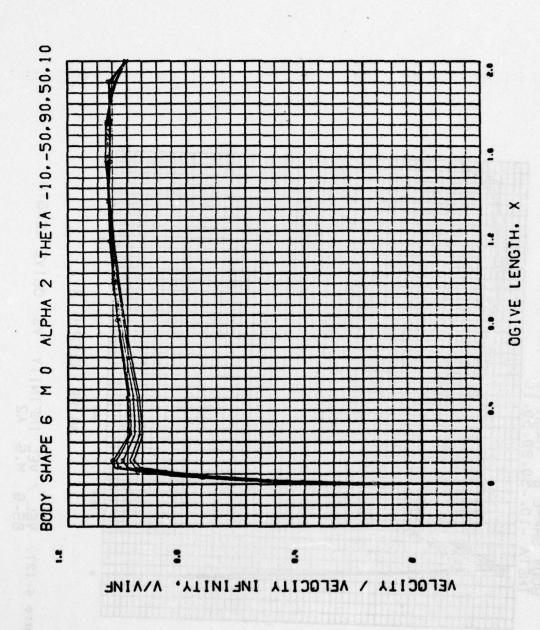
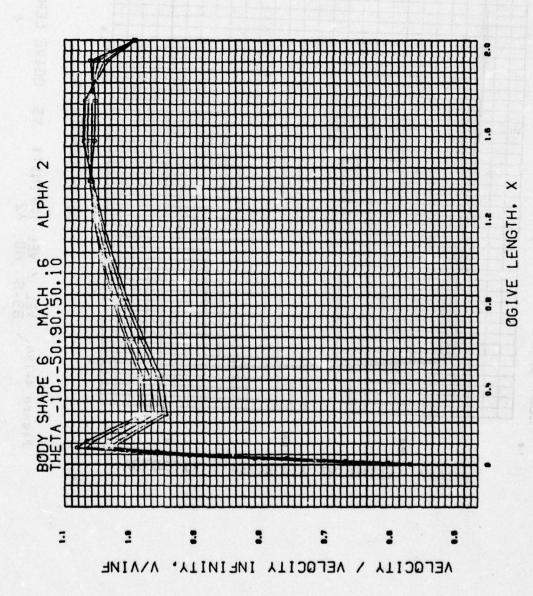


Figure 4-126. VEL / VEL INFINITY VS OGIVE LENGTH BS-6 M0 A2



igure 4-127. VEL / VEL INFINITY VS OGIVE LENGTH BS-6 M.6 A2

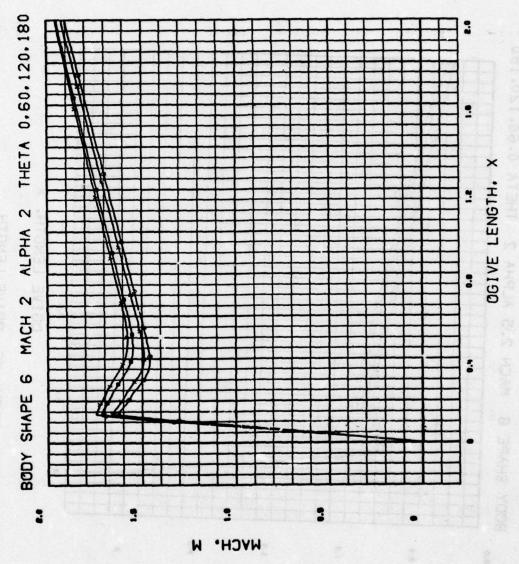


Figure 4-128. MACH VS OGIVE LENGTH BS-6 M2 A2

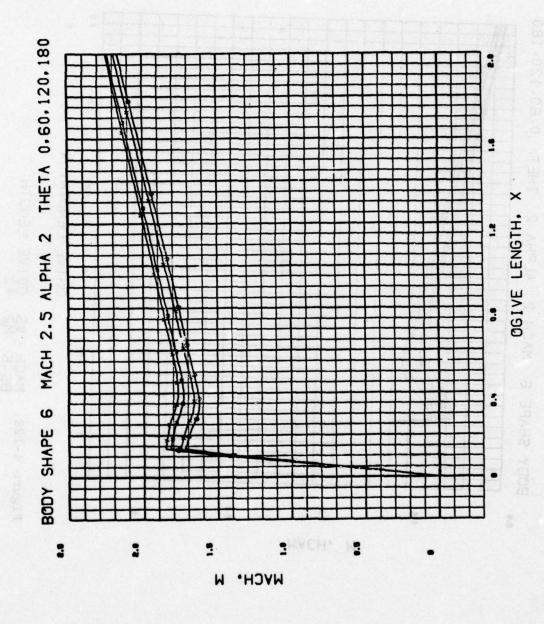


Figure 4-129. MACH VS OGIVE LENGTH BS-6 M2.5 A2

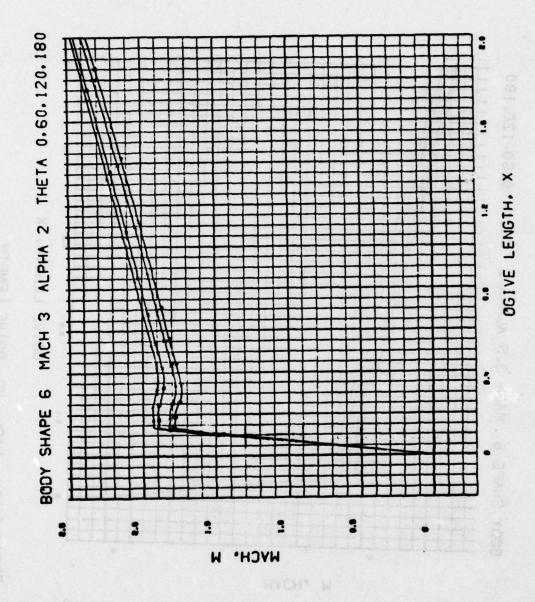


Figure 4-130. MACH VS OGIVE LENGTH BS-6 M3 A2

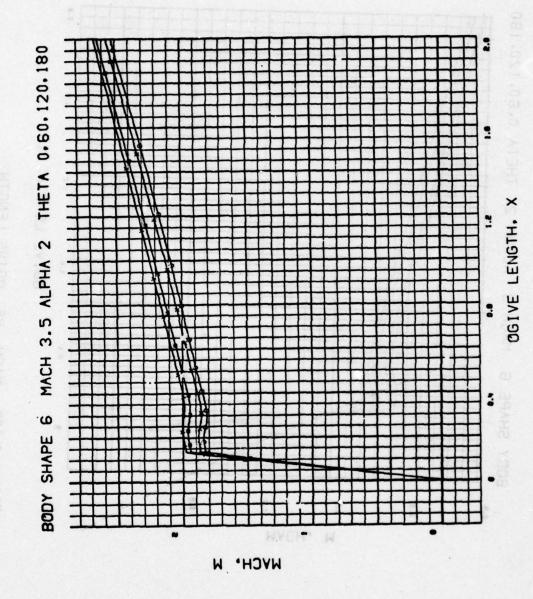


Figure 4-131. MACH VS 0GIVE LENGTH BS-6 M3.5 A2

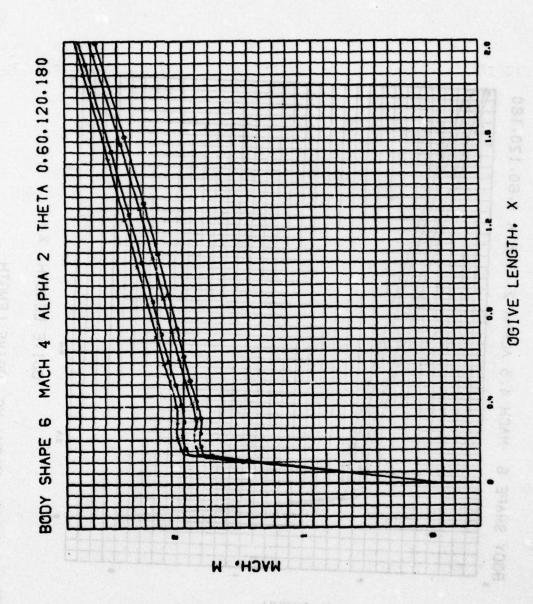


Figure 4-132. MACH VS OGIVE LENGTH BS-6 M4 A2

084

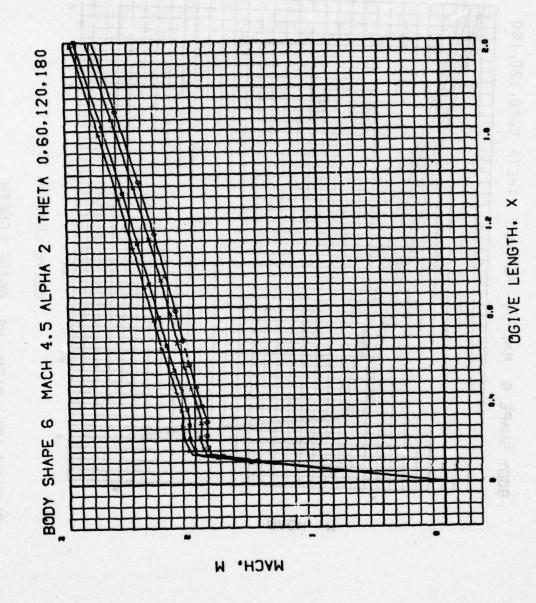
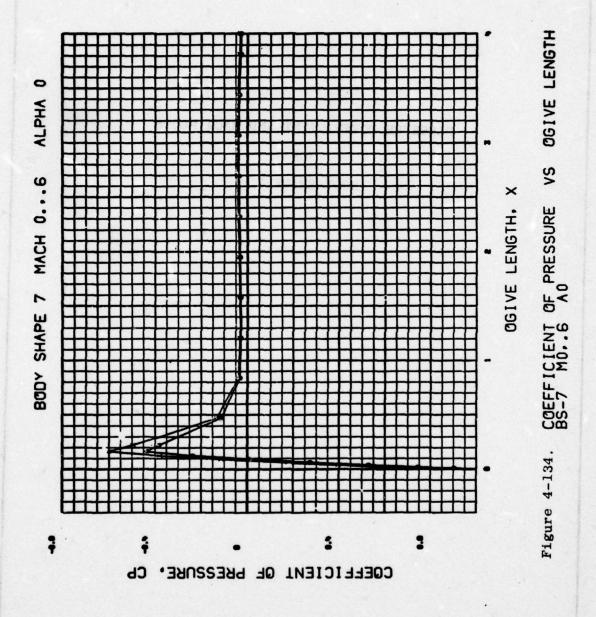


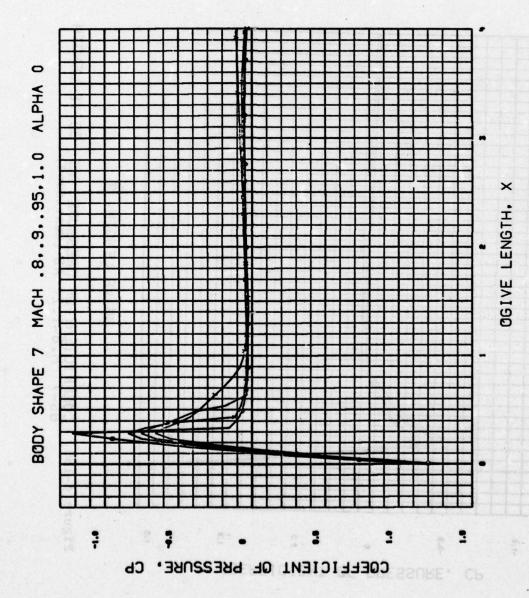
Figure 4-133. MACH VS OGIVE LENGTH BS-6 M4.5 A2

PRESSURE COEFFICIENT AND MACH PLOTS

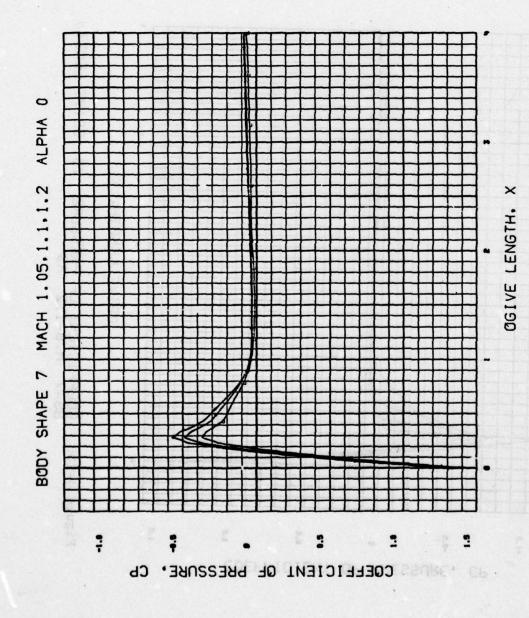
FOR

BODY SHAPE 7

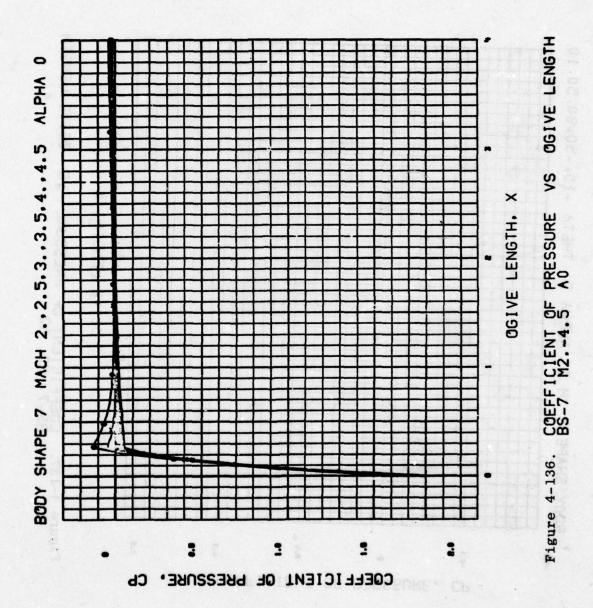


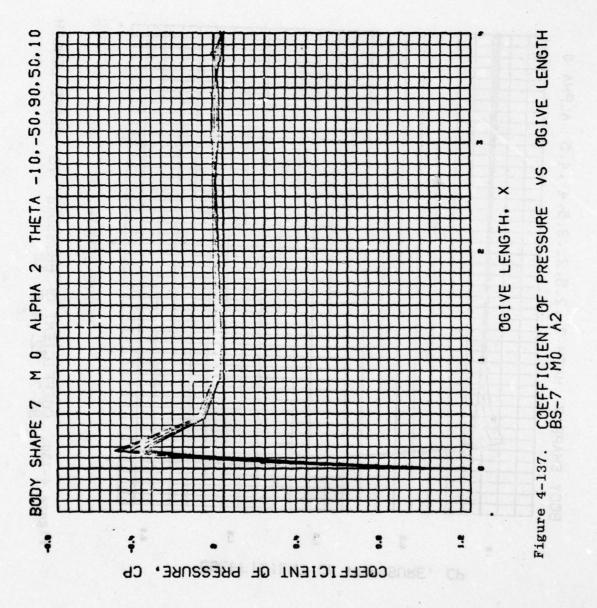


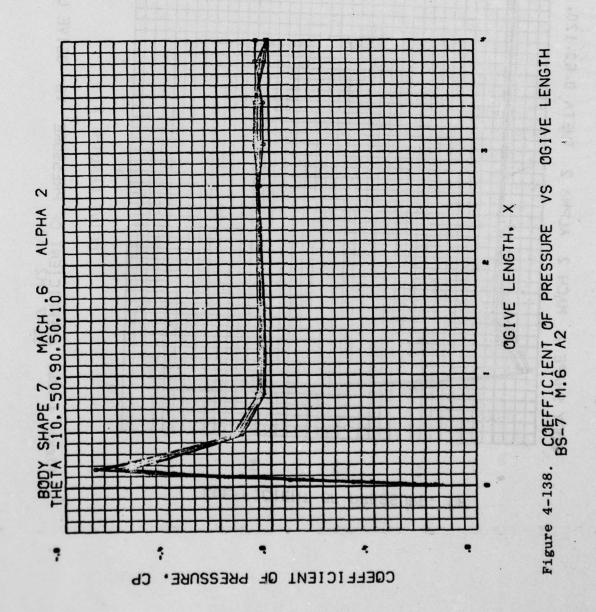
OGIVE LENGTH Figure 4-135. COEFFICIENT OF PRESSURE VS BS-7 M.8-1.2 A0



OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-7 M.8-1.2 A0 (Continued) Figure 4-135.







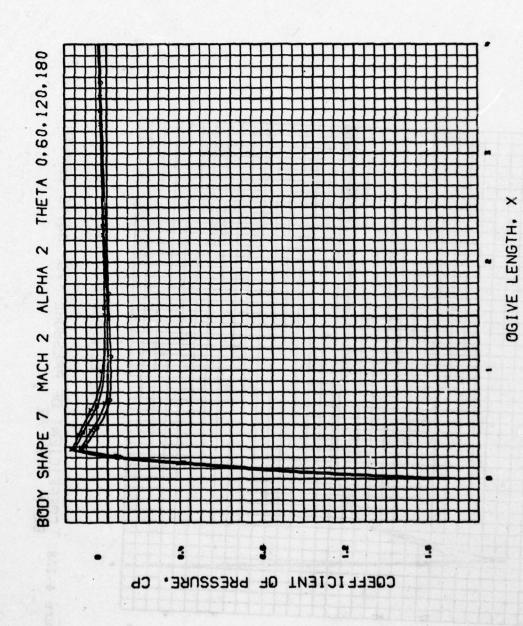


Figure 4-139. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-7 M2 A2

CREFFICIENT OF PRESSURE, CP

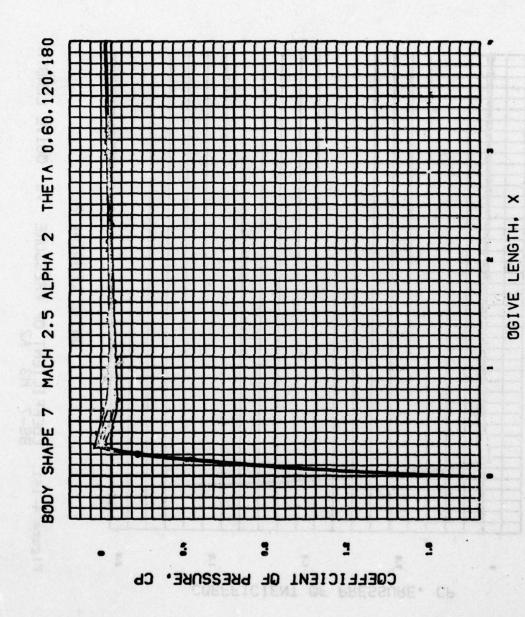
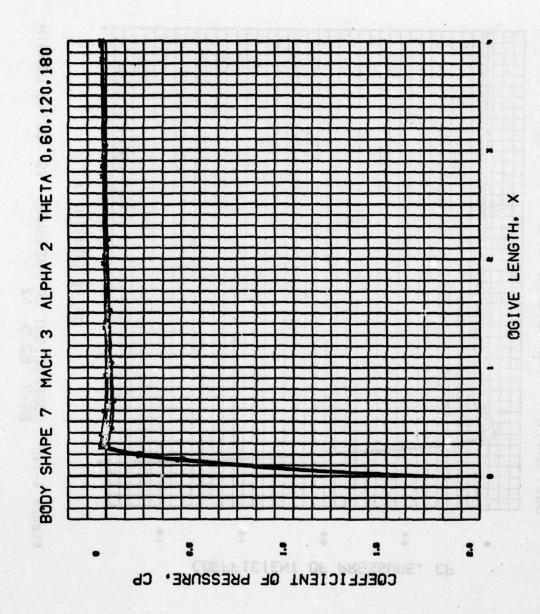
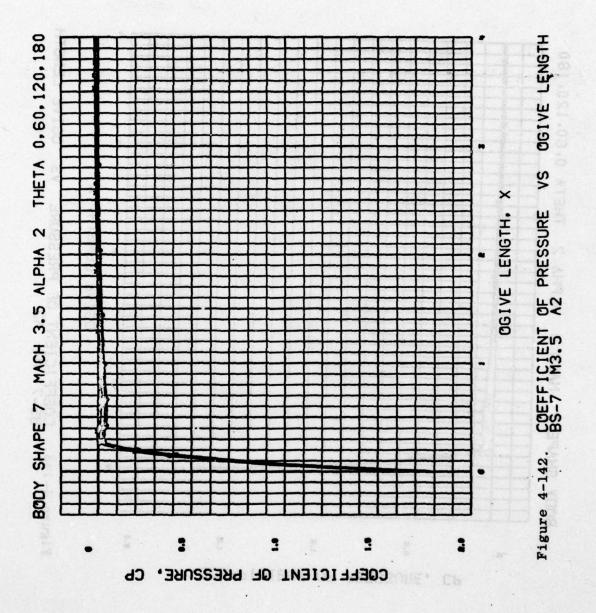


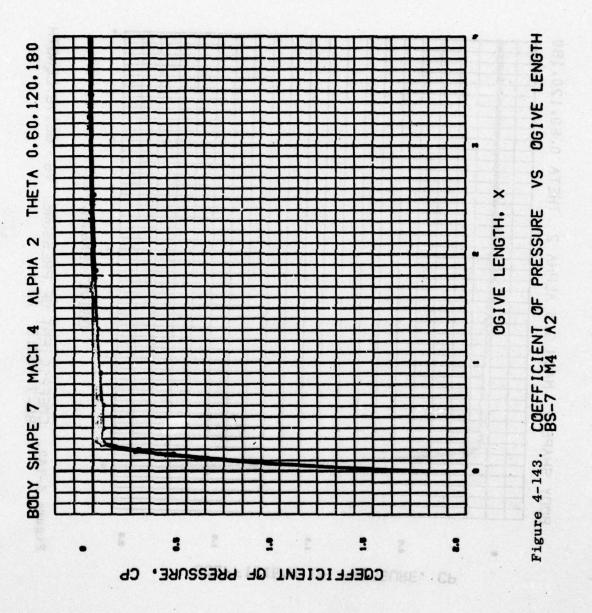
Figure 4-140. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-7 M2.5 A2

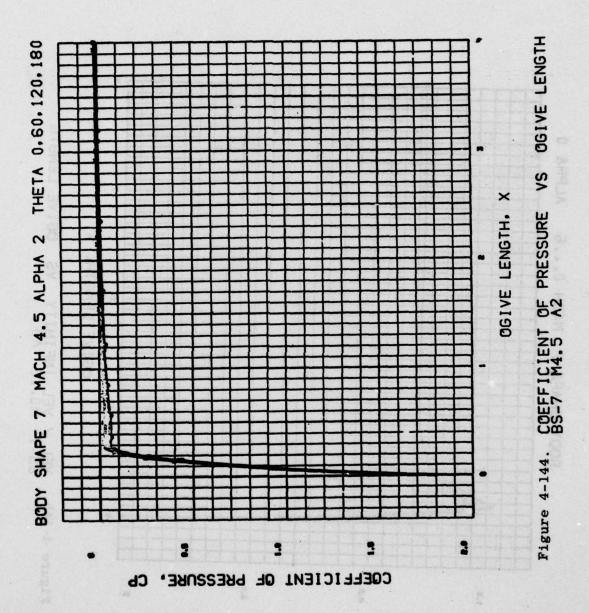


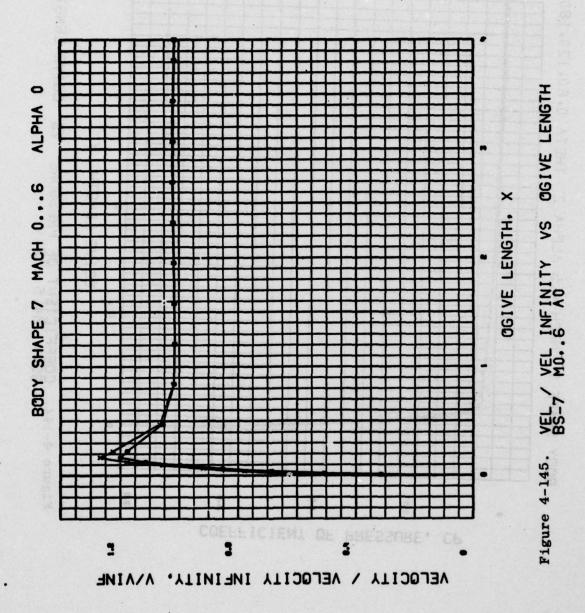
OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-7 M3 A2 Figure 4-141.



- 171







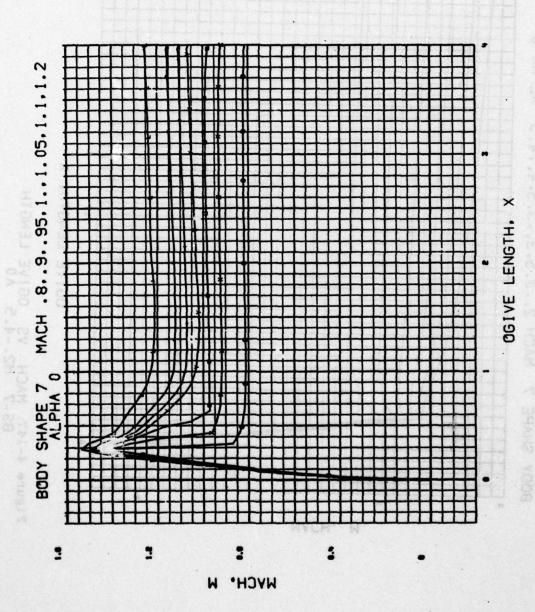


Figure 4-146. MACH VS OGIVE LENGTH BS-7 M.8-1.2 A0

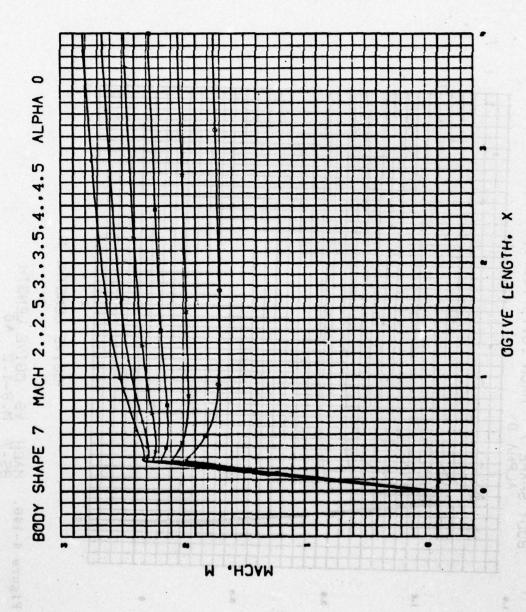


Figure 4-147. MACH VS OGIVE LENGTH BS-7 M2.-4.5 A0

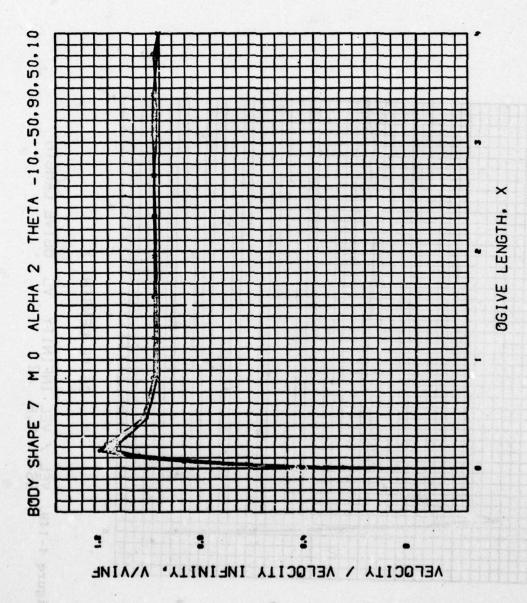


Figure 4-148. VEL / VEL INFINITY VS OGIVE LENGTH BS-7 M0 A2

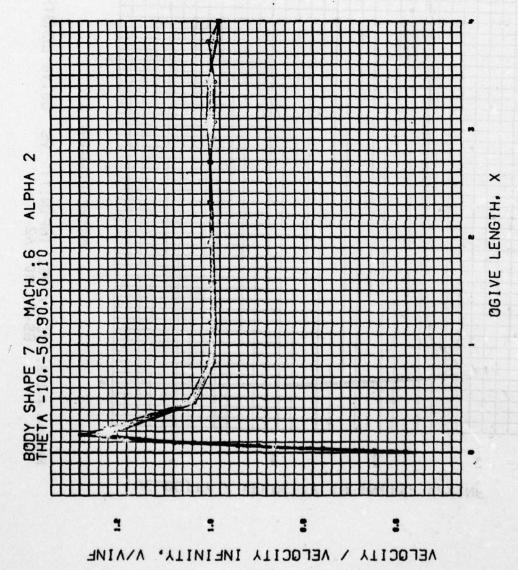
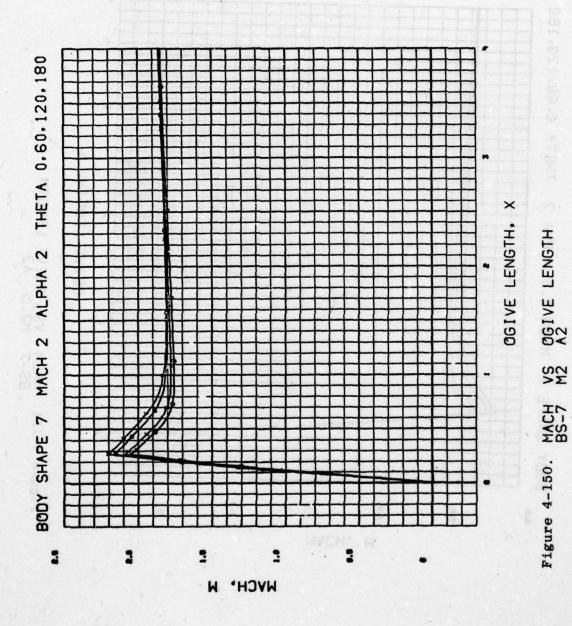


Figure 4-149. VEL / VEL INFINITY VS OGIVE LENGTH BS-7 M.6 A2



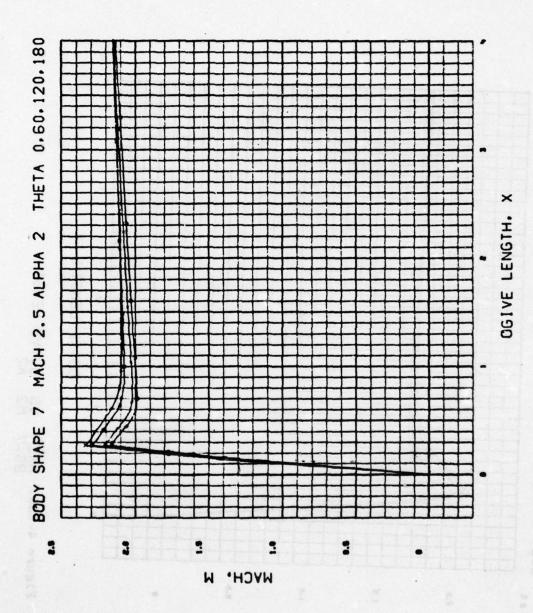
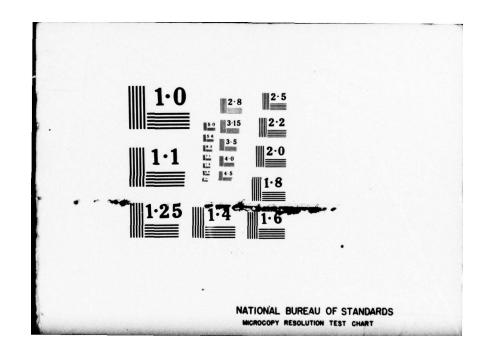


Figure 4-151. MACH VS OGIVE LENGTH BS-7 M2.5 A2

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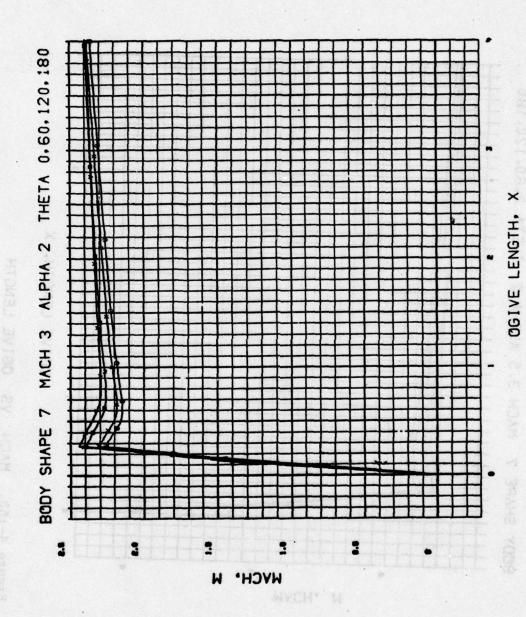


Figure 4-152. MACH VS OGIVE LENGTH BS-7 M3 A2

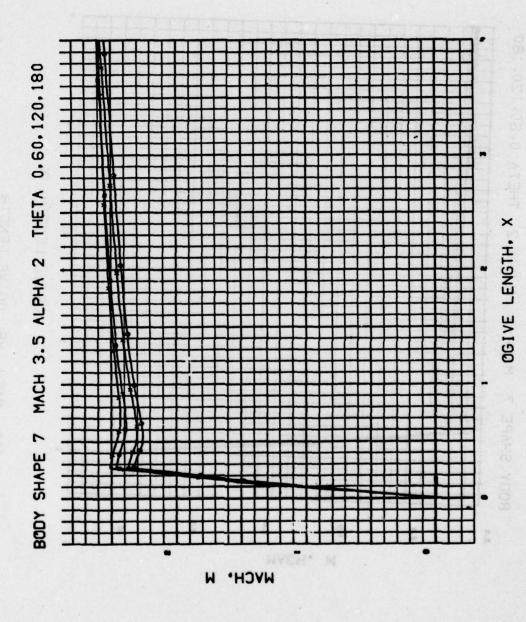


Figure 4-153. MACH VS 0GIVE LENGTH BS-7 M3.5 A2

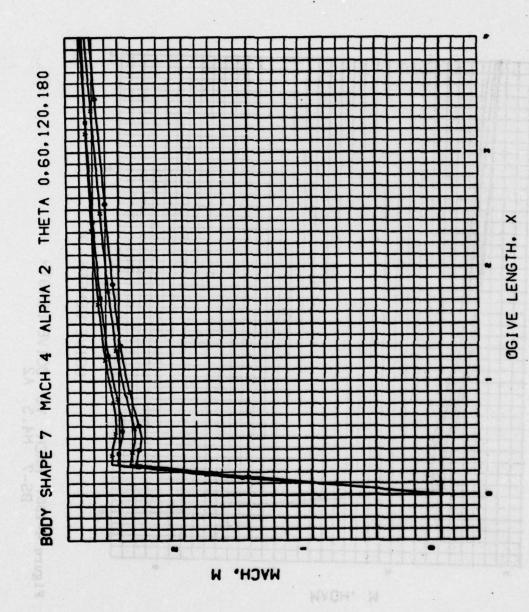


Figure 4-154. MACH VS OGIVE LENGTH BS-7 M4 A2

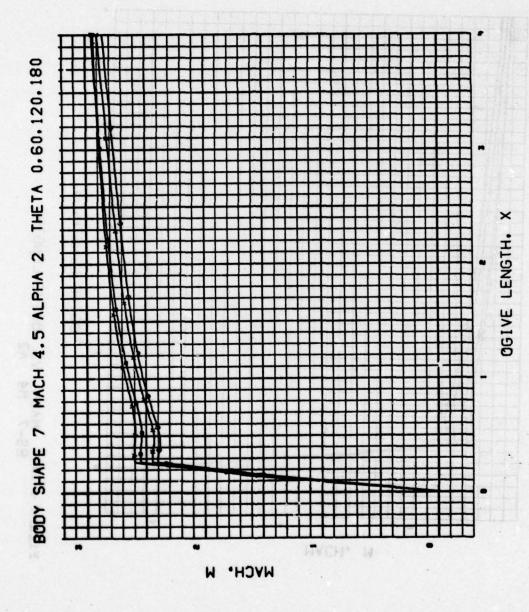


Figure 4-155. MACH VS 0GIVE LENGTH BS-7 M4.5 A2

PRESSURE COEFFICIENT AND MACH PLOTS

FOR

BODY SHAPE 8

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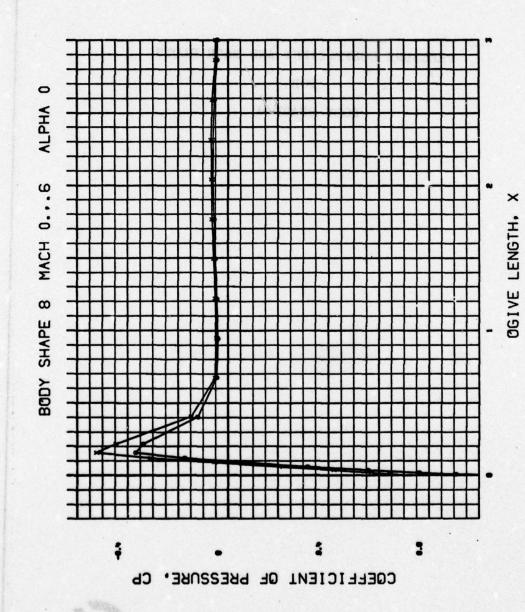
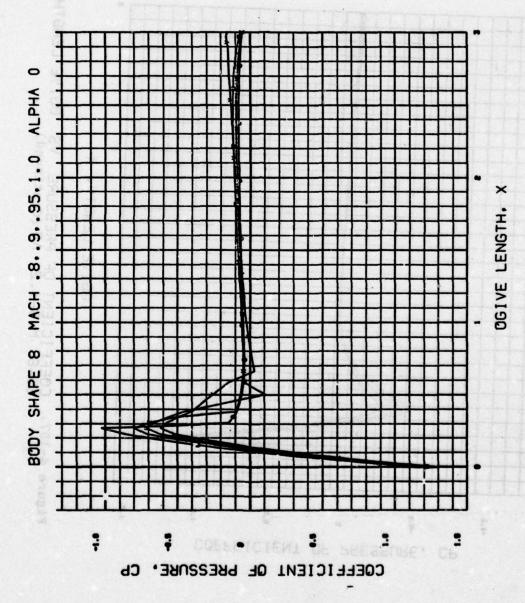
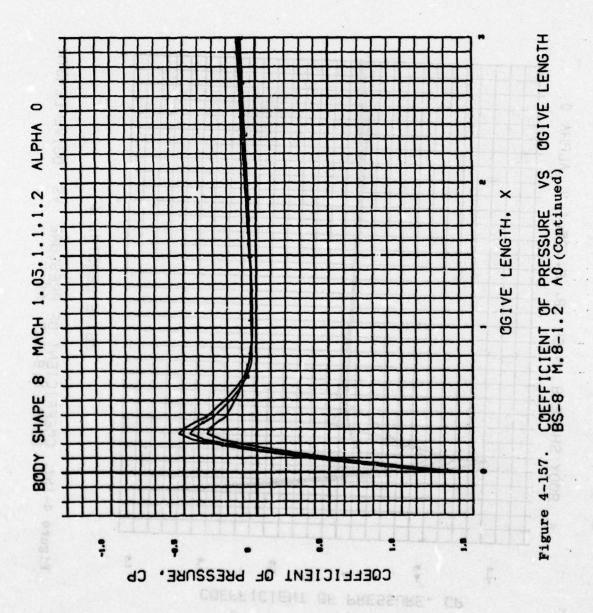


Figure 4-156. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-8 MO..6 A0



OGIVE LENGTH ۸S Figure 4-157. COEFFICIENT OF PRESSURE BS-8 M.8-1.2 A0



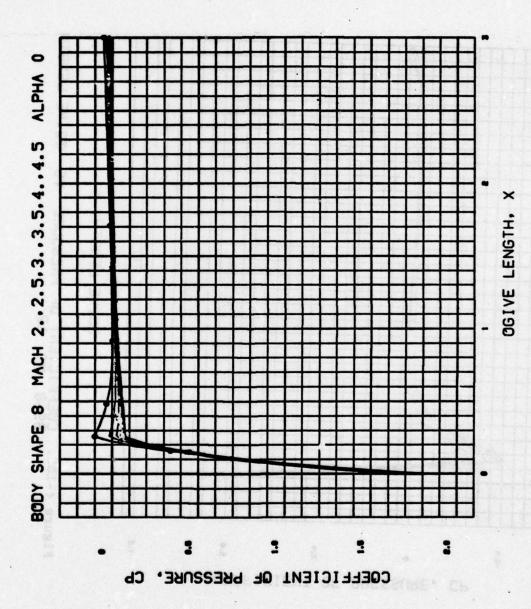
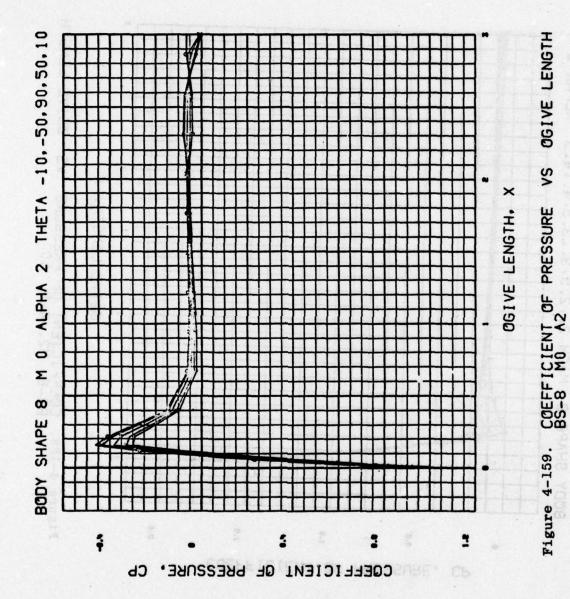
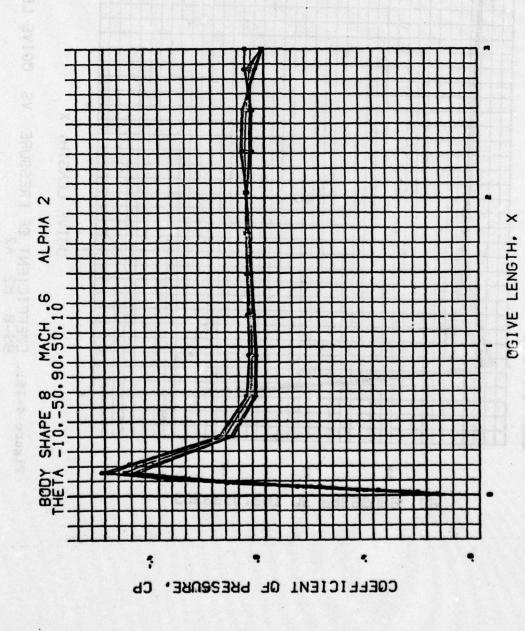


Figure 4-158. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-8 M2.-4.5 A0





VS OGIVE LENGTH Figure 4-160. COEFFICIENT OF PRESSURE BS-8 M.6 A2

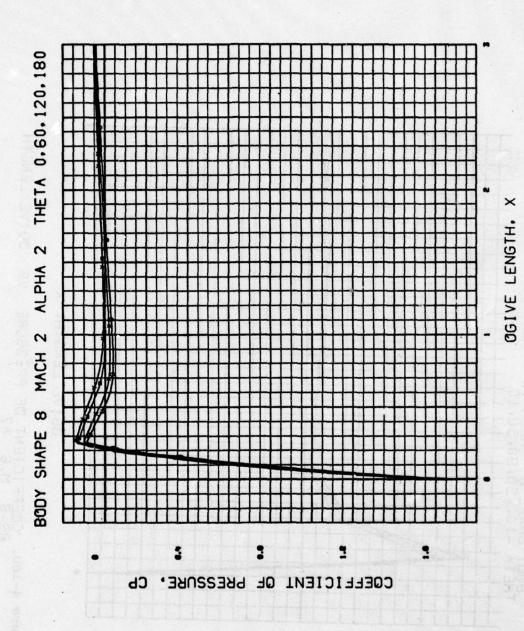
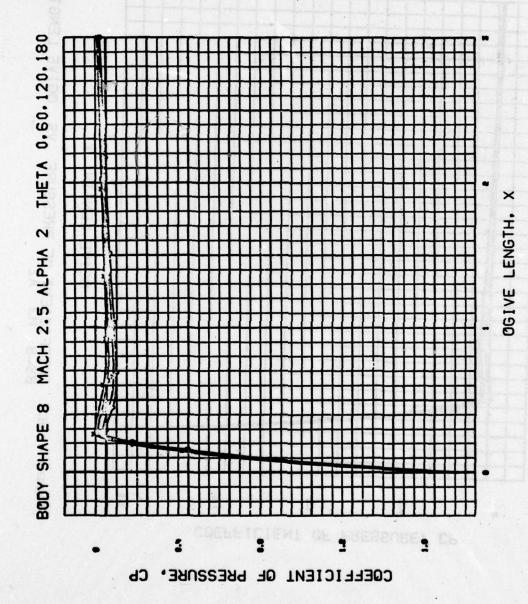
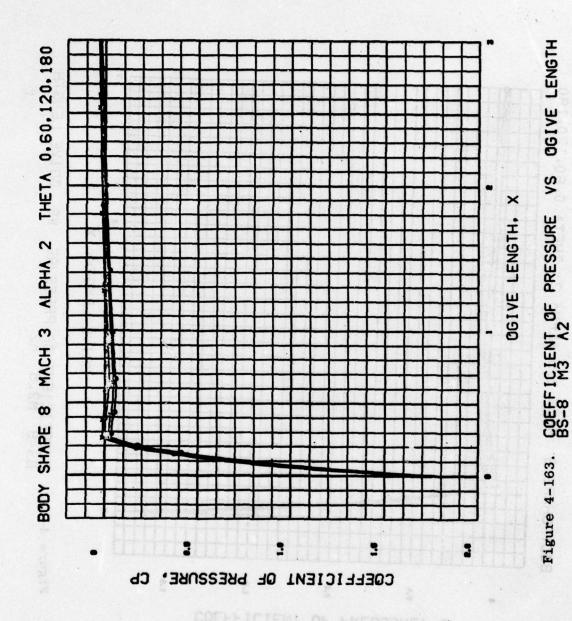
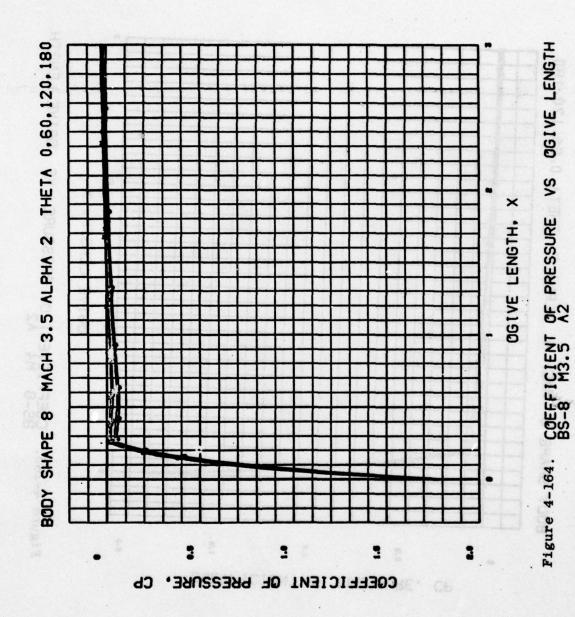


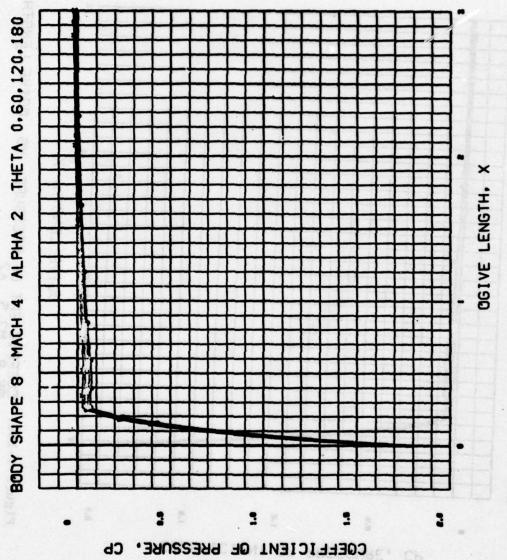
Figure 4-161. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-8 M2 A2



OGIVE LENGTH ۸S COEFFICIENT OF PRESS IRE BS-8 M2.5 A2 Figure 4-162.







COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-8 M4 A2 Figure 4-165.

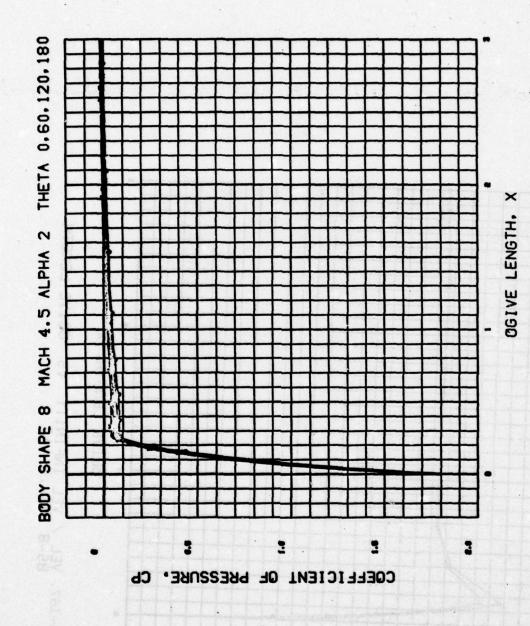


Figure 4-166. COEFFICIENT OF PRESSURE VS OGIVE LENGTH

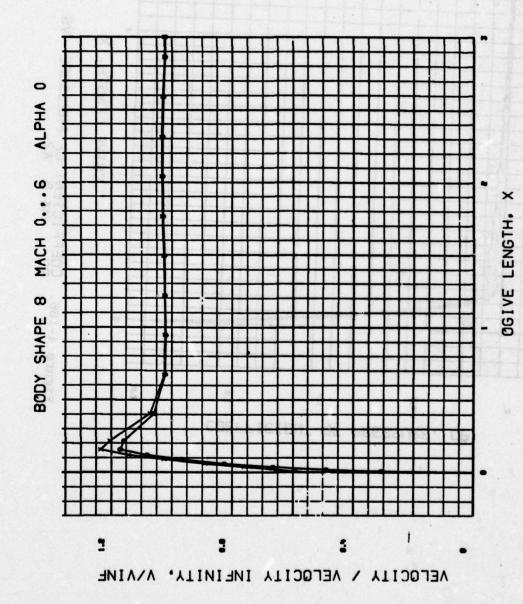


Figure 4-167. VEL / VEL INFINITY VS OGIVE LENGTH BS-8 MO..6 A0

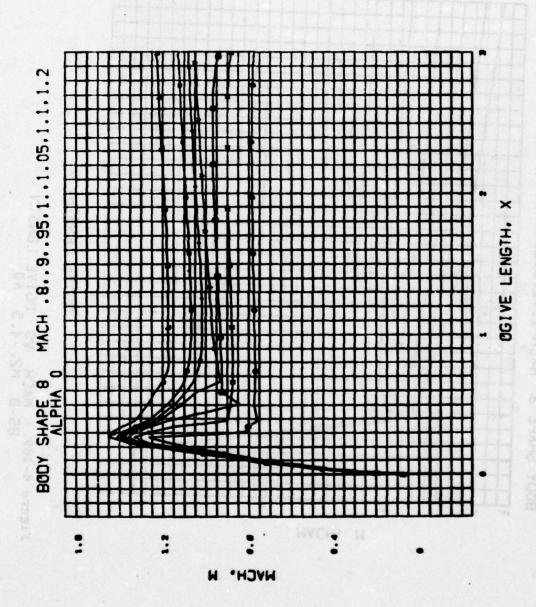


Figure 4-168. MACH VS OGIVE LENGTH BS-8 M.8-1.2 A0

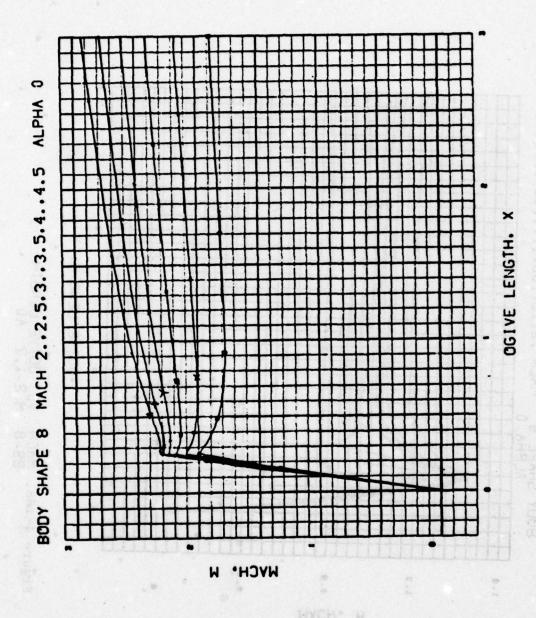


Figure 4-169. MACH VS 061VE LENGTH BS-8 M2.-4.5 A0

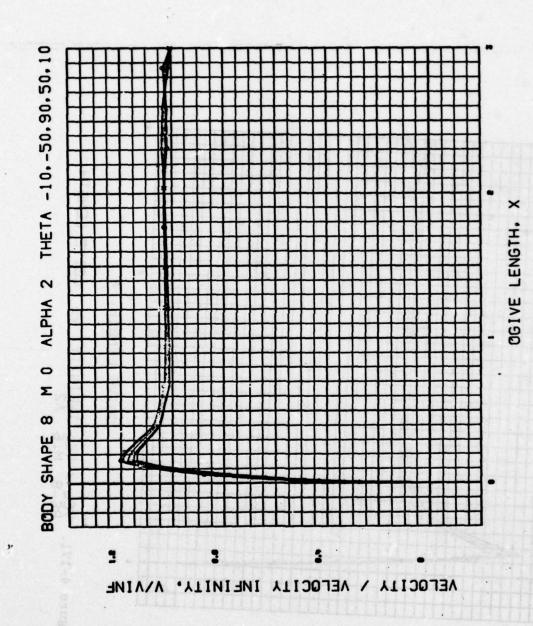


Figure 4-170. VEL / VEL INFINITY VS OGIVE LENGTH

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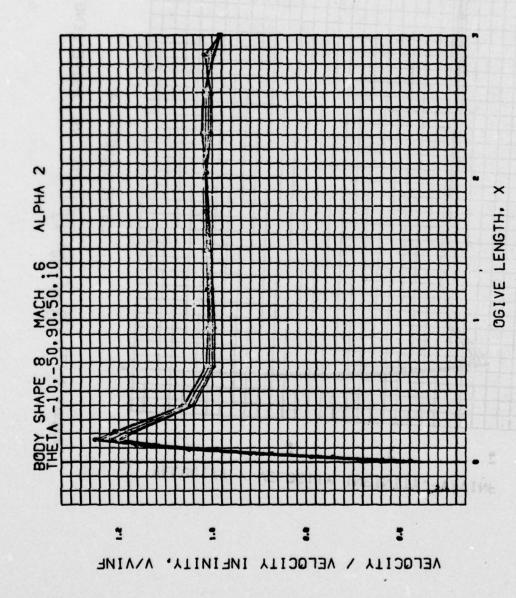


Figure 4-171. VEL / VEL INFINITY VS OGIVE LENGTH BS-8 M.6 A2

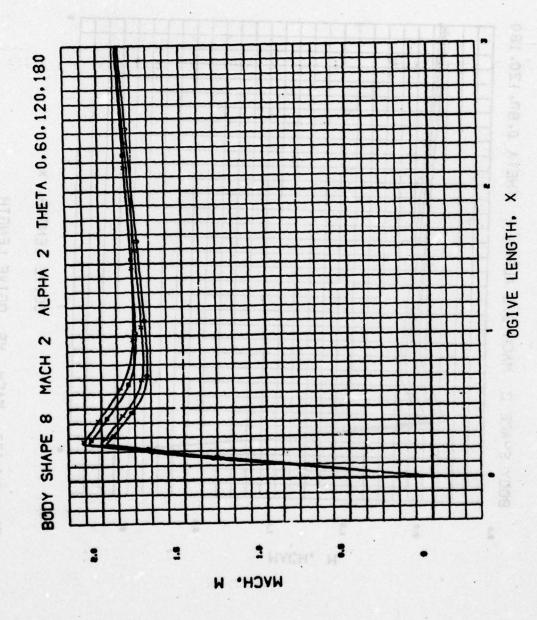


Figure 4-172. MACH VS 06IVE LENGTH BS-8 M2 A2

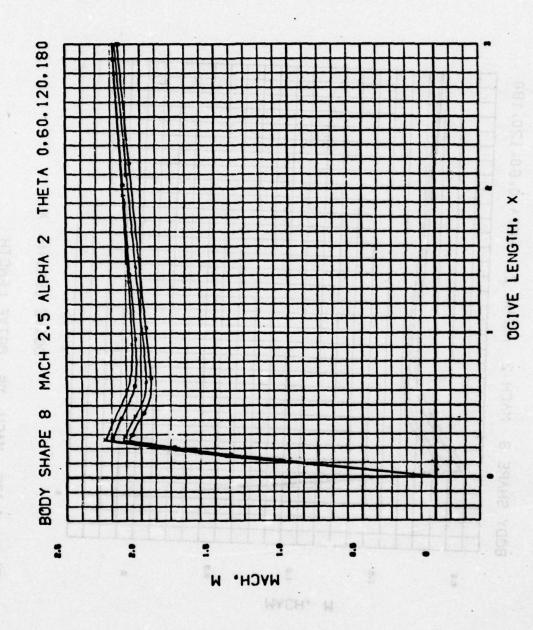


Figure 4-173. MACH VS 061VE LENGTH 85-8 M2.5 A2

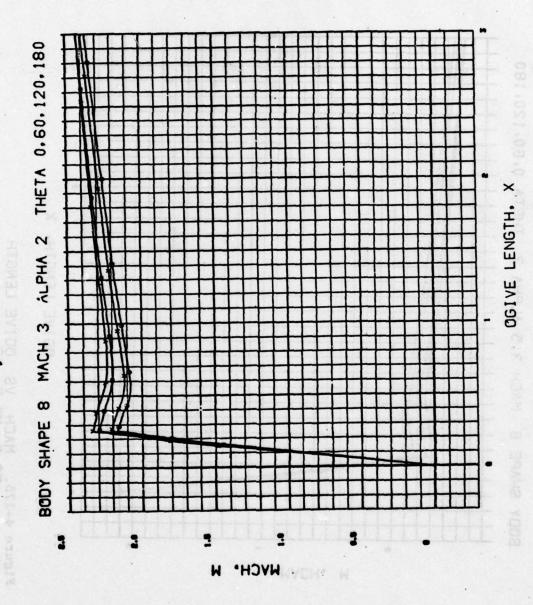


Figure 4-174. MACH VS OGIVE LENGTH BS-8 M3 A2

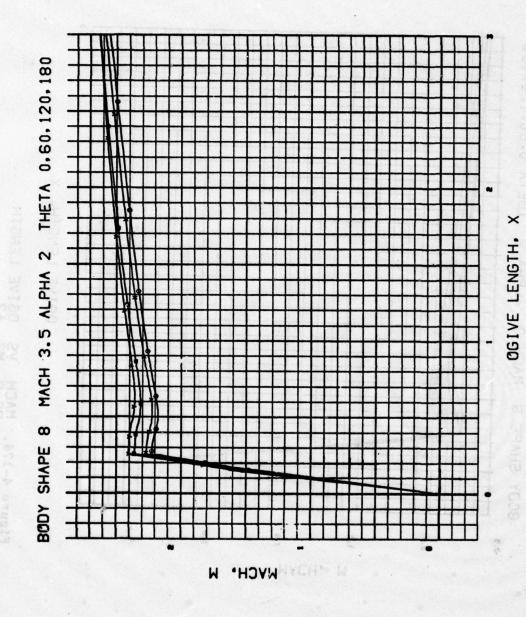


Figure 4-175. MACH VS OGIVE LENGTH BS-8 M3.5 A2

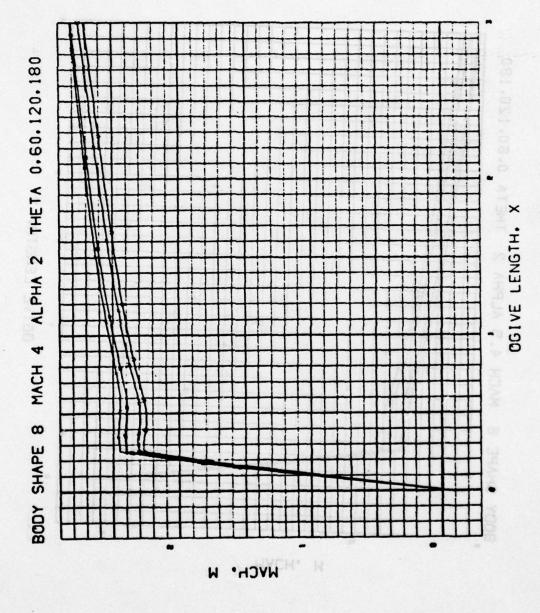


Figure 4-176. MACH VS OGIVE LENGTH BS-8 M4 A2

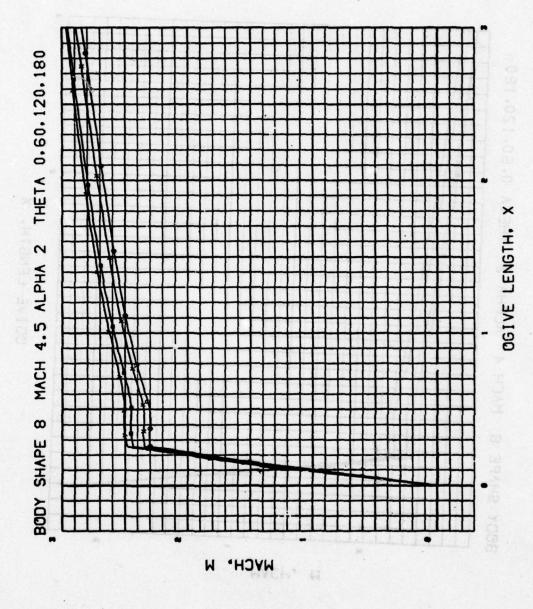


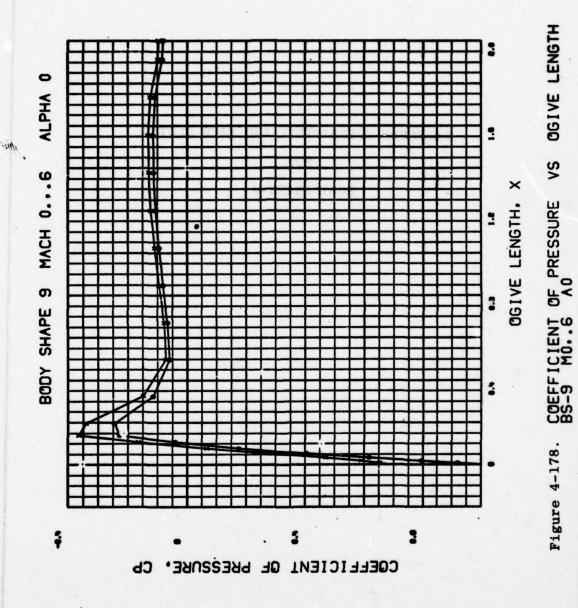
Figure 4-177, MACH VS 06IVE LENGTH BS-8 M4.5 A2

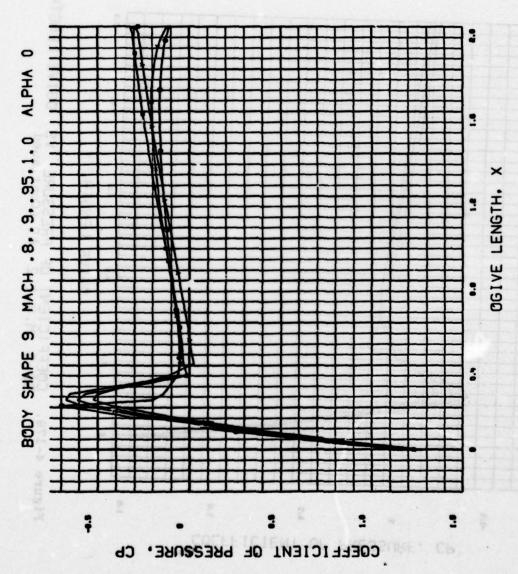
PRESSURE COEFFICIENT AND MACH PLOTS

FOR

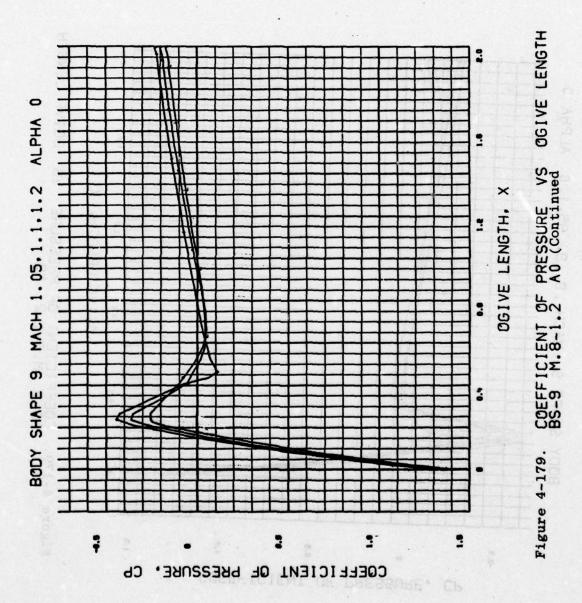
BODY SHAPE 9

COEFFICIENT OF PRESSURE, CP.





OGIVE LENGTH ٧S BS-9 M.8-1.2 A0 Figure 4-179.



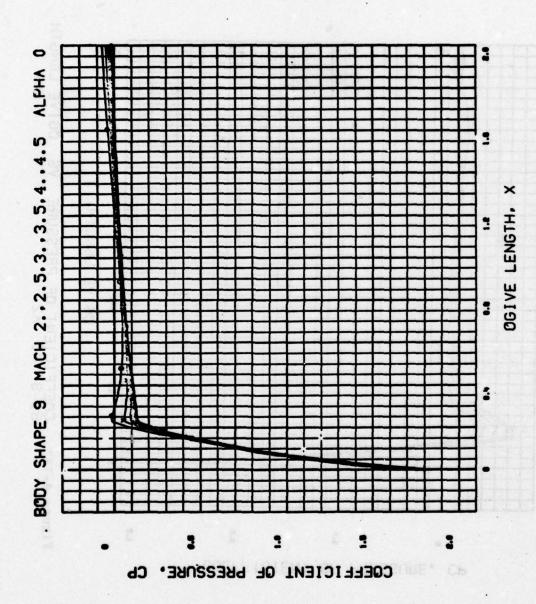
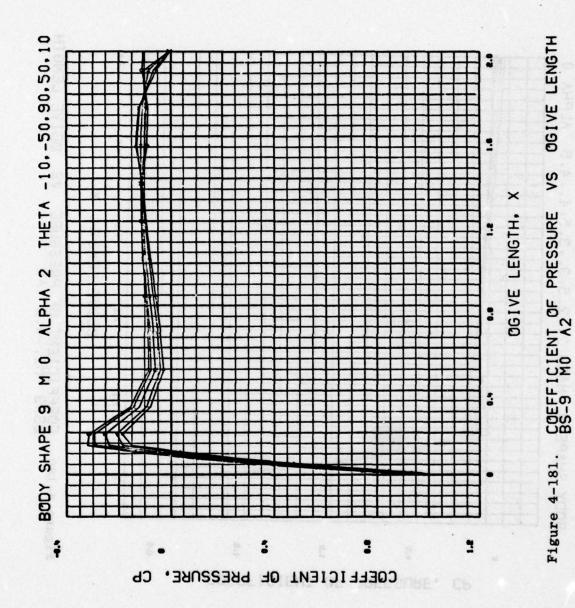
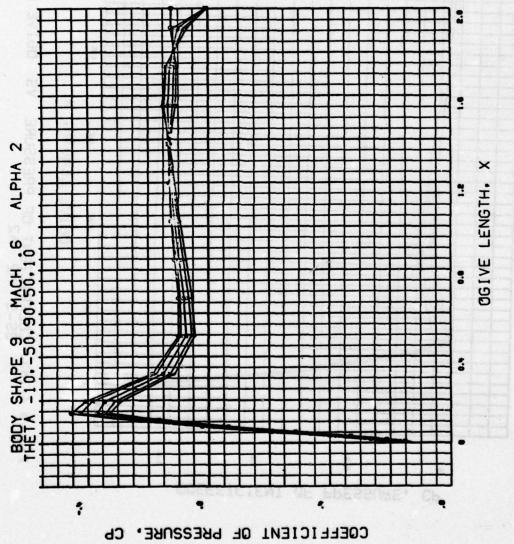
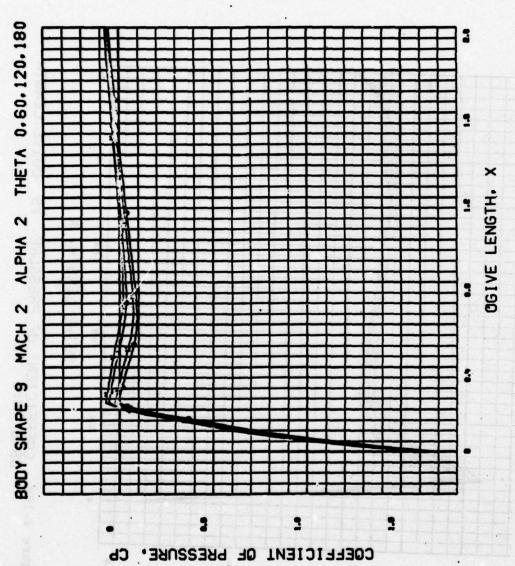


Figure 4-180. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-9 M2.-4.5 A0





DGIVE LENGTH ٧S Figure 4-182. COEFFICIENT OF PRESSURE BS-9 M.6 A2



OGIVE LENGTH ۸S Figure 4-183. COEFFICIENT OF PRESSURE BS-9 M2 A2

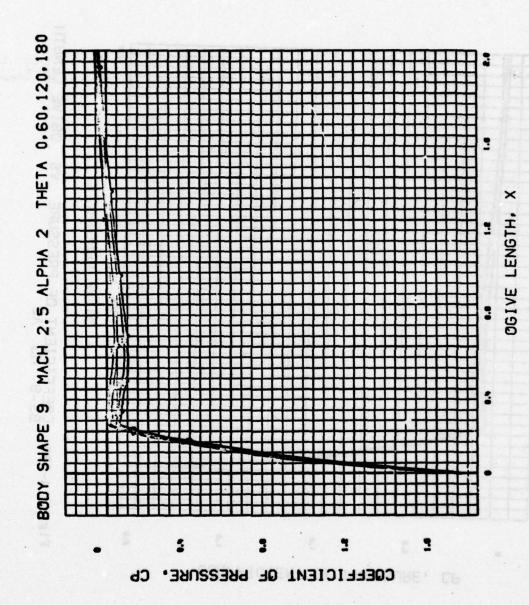
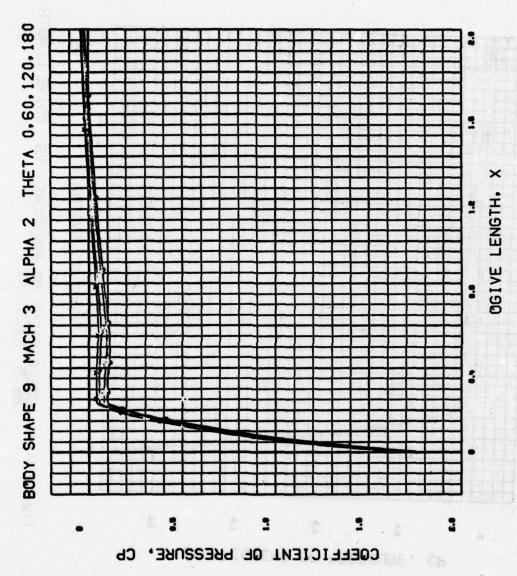
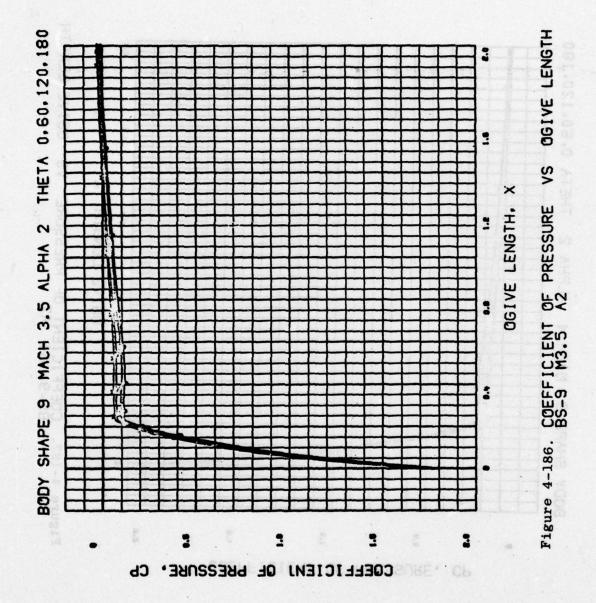


Figure 4-184. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-9 M2.5 A2



OGIVE LENGTH ۸S Figure 4-185. COEFFICIENT OF PRESSURE BS-9 M3 A2



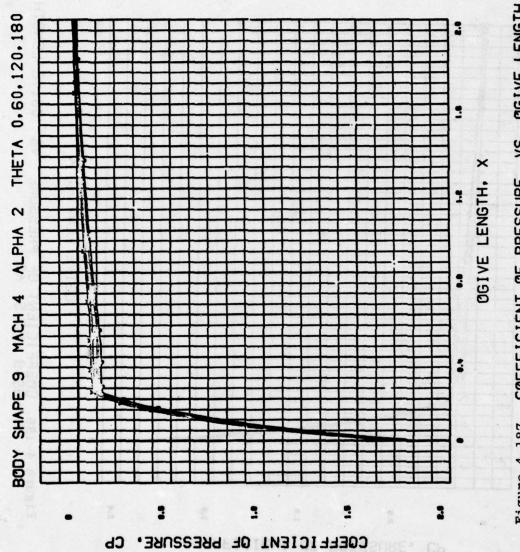
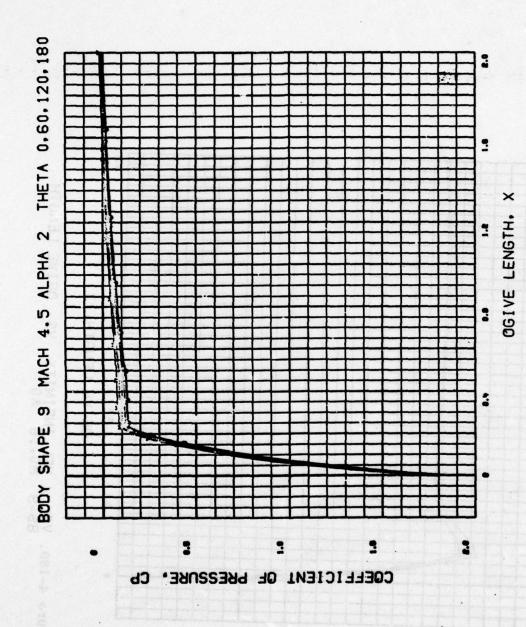
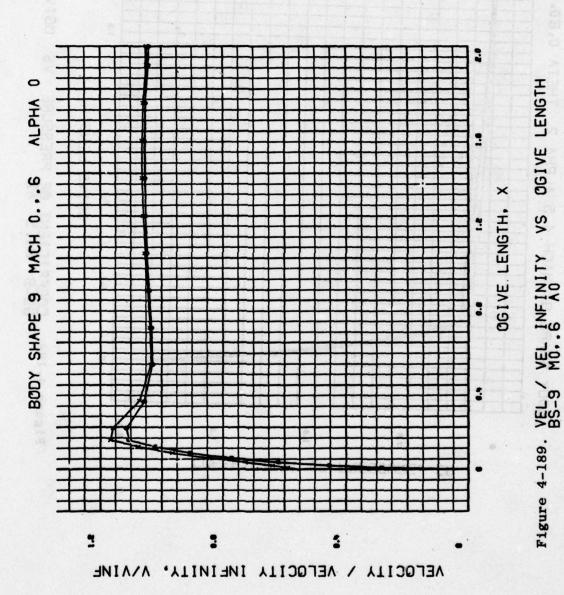


Figure 4-187. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-9 M4 A2



OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-9 M4.5 A2 Figure 4-188.



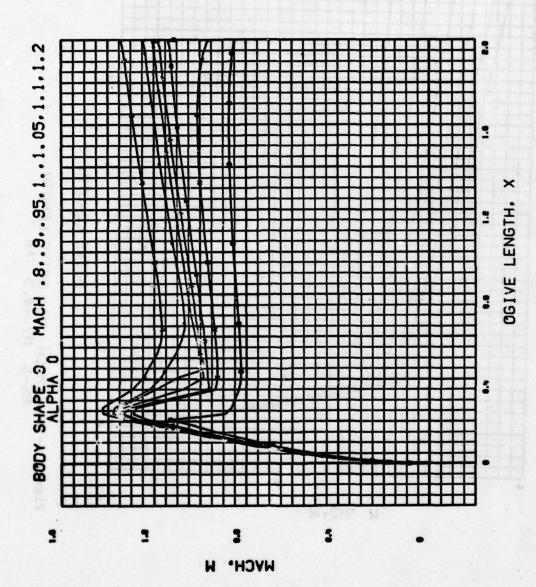


Figure 4-190. MACH VS OGIVE LENGTH BS-9 M.8-1.2 A0

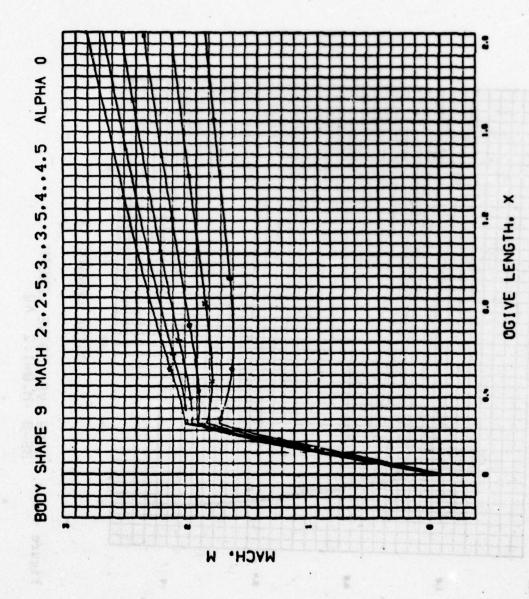


Figure 4-191. MACH VS 0GIVE LENGTH 85-9 M2.-4.5 A0

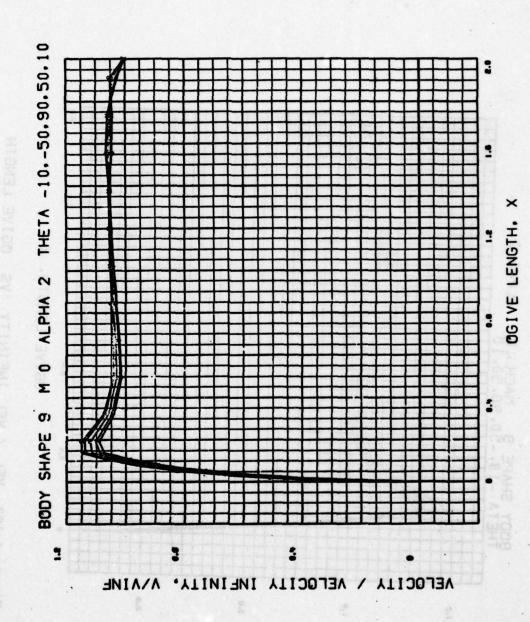


Figure 4-192. VEL / VEL INFINITY VS OGIVE LENGTH BS-9 MO A2

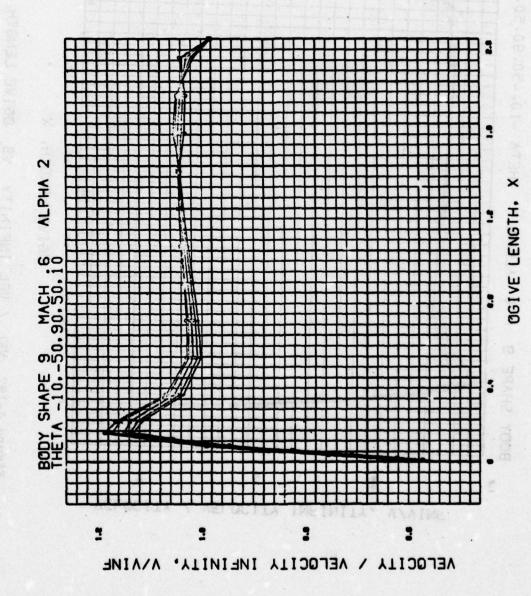


Figure 4-193. VEL / VEL INFINITY VS OGIVE LENGTH BS-9 M.6 A2

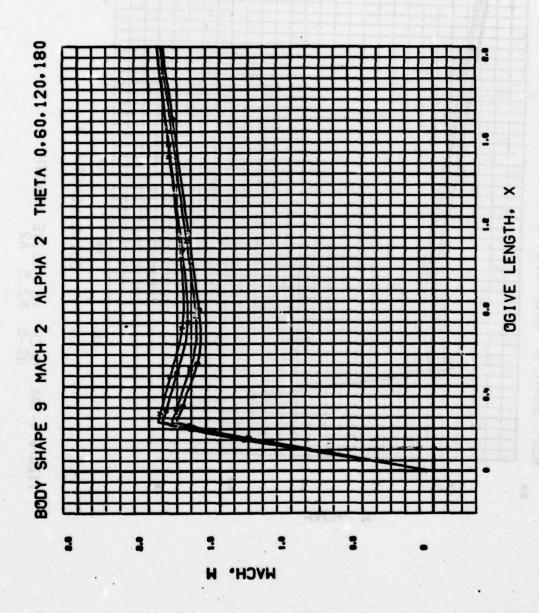


Figure 4-194. MACH VS 06IVE LENGTH BS-9 M2 A2

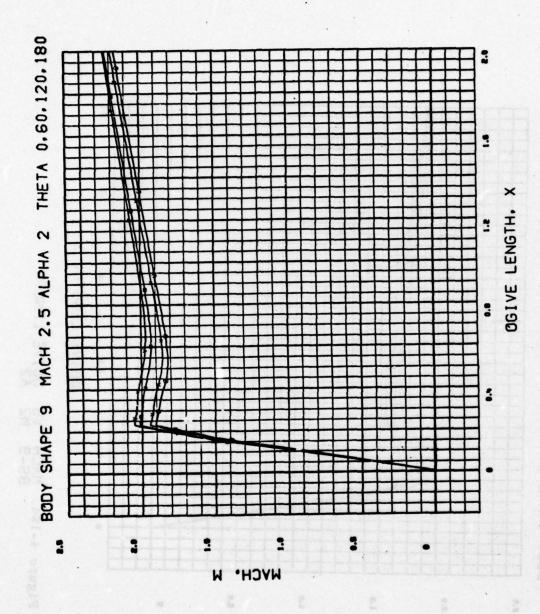


Figure 4-195. MACH VS OGIVE LENGTH BS-9 M2.5 A2

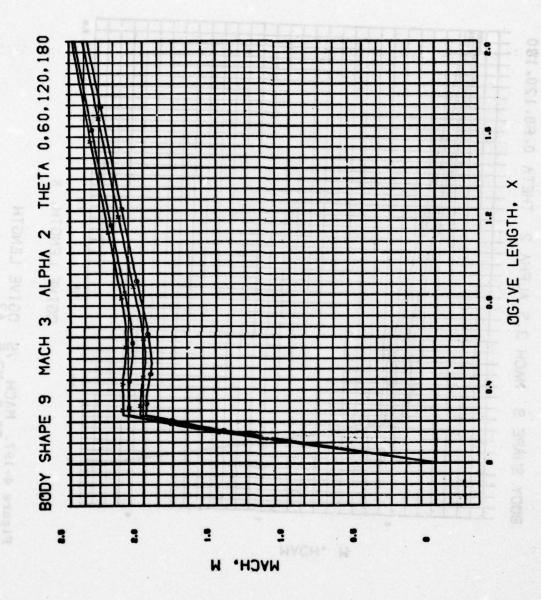


Figure 4-196. MACH VS OGIVE LENGTH BS-9 M3 A2

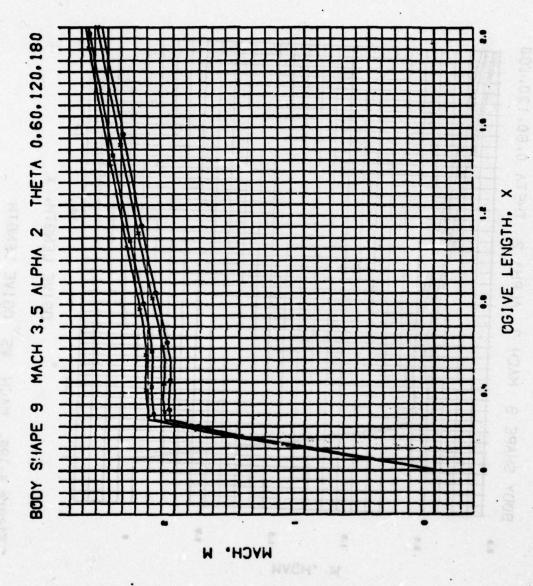


Figure 4-197. MACH VS 061VE LENGTH BS-9 M3.5 A2

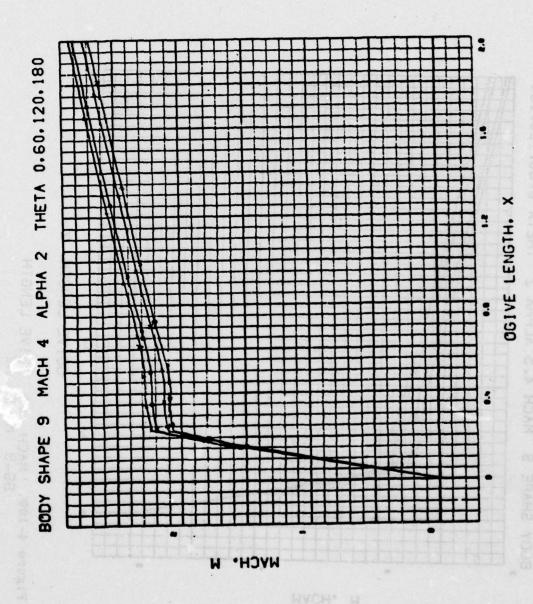


Figure 4-198. MACH VS OGIVE LENGTH BS-9 M4 A2

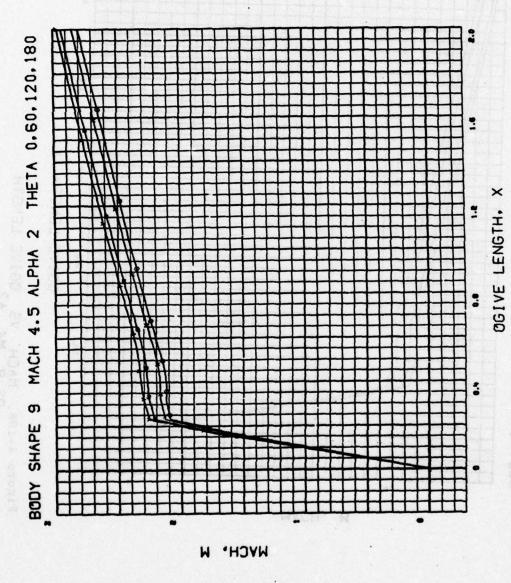


Figure 4-199. MACH VS 0GIVE LENGTH BS-9 M4.5 A2

PRESSURE COEFFICIENT AND MACH PLOTS
FOR

BODY SHAPE 10



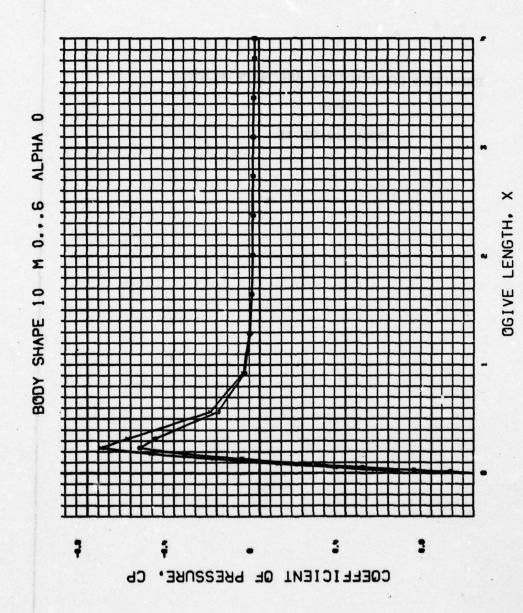
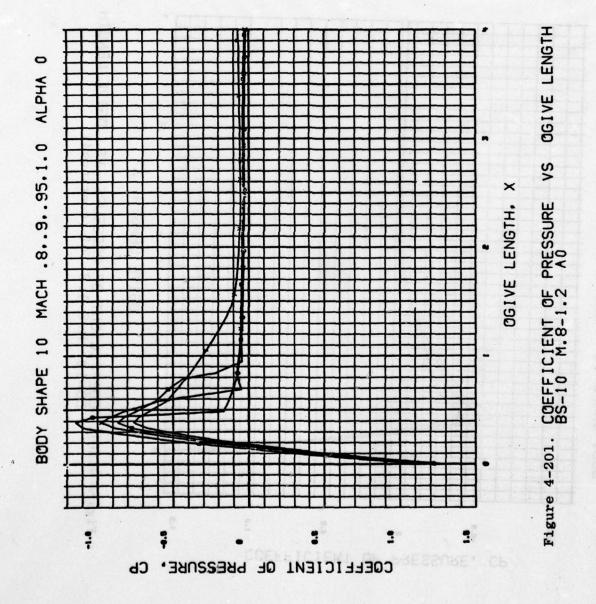


Figure 4-200. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-10 M0..6 A0



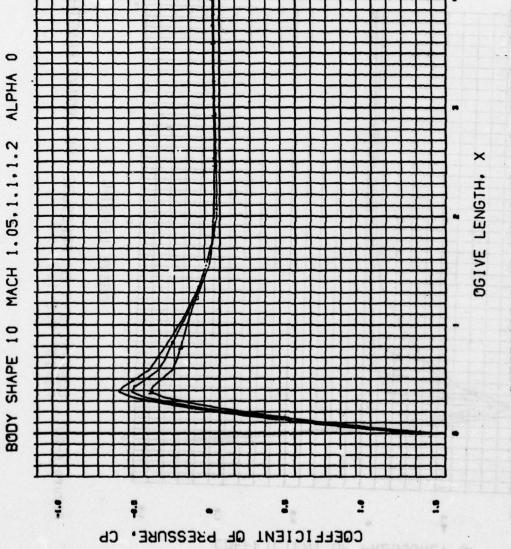
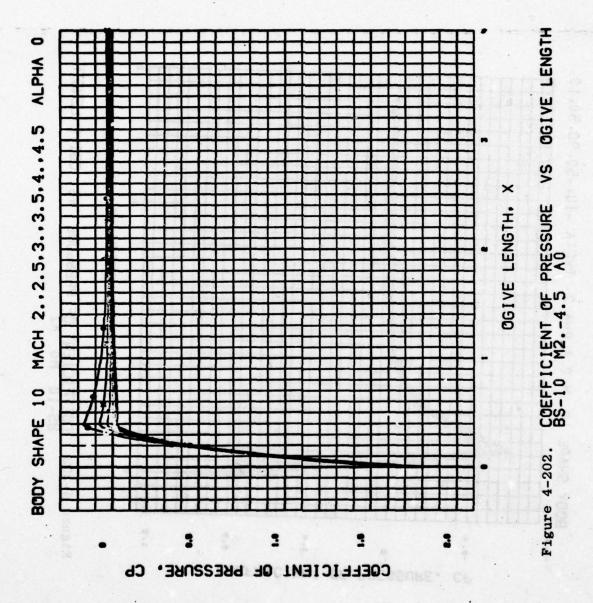
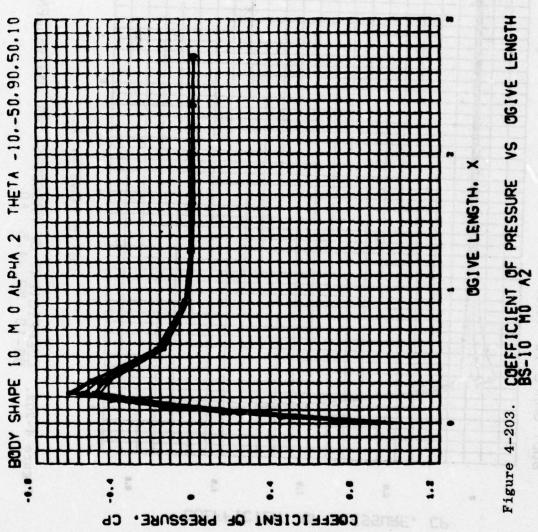
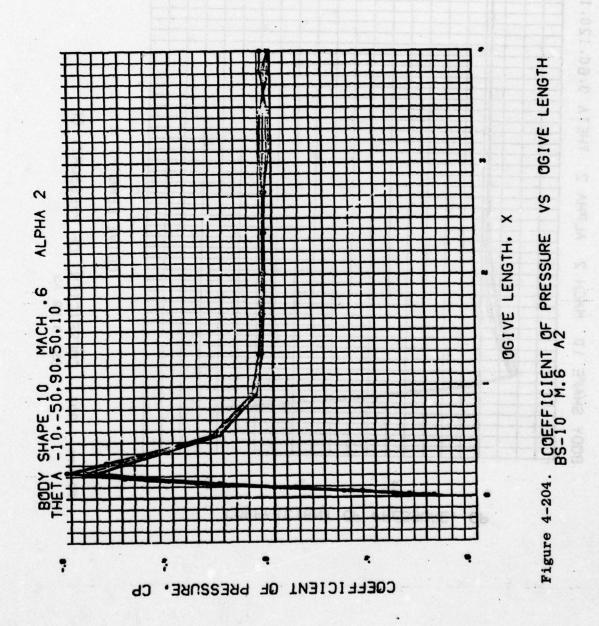


Figure 4-201. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-10 M.8-1.2 A0 (Continued)







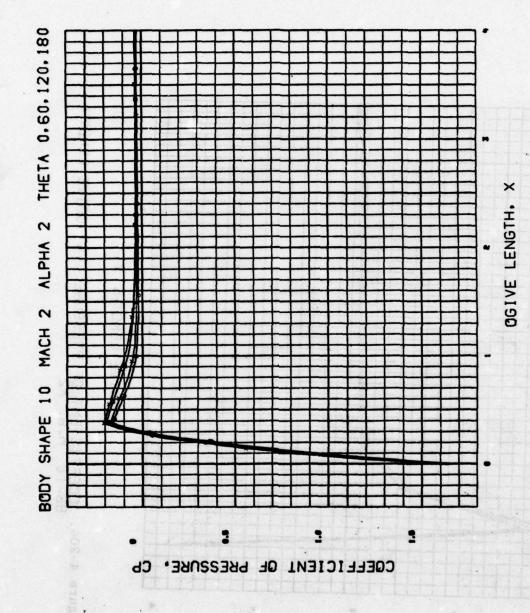


Figure 4-205. COEFFICIENT OF PRESSURE, CP BS-10 M2 A2

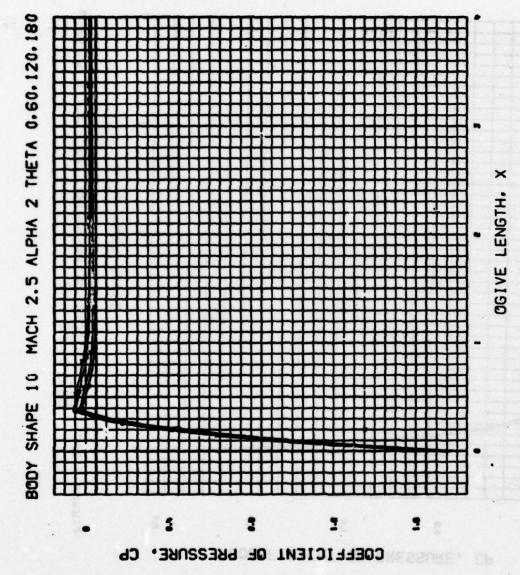
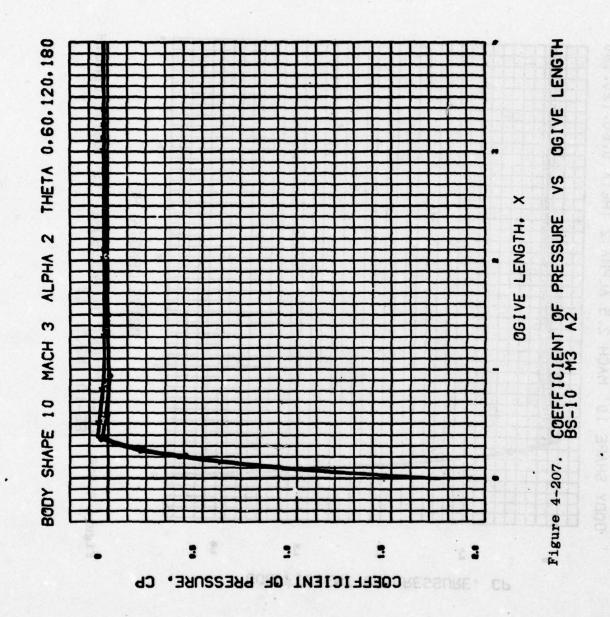
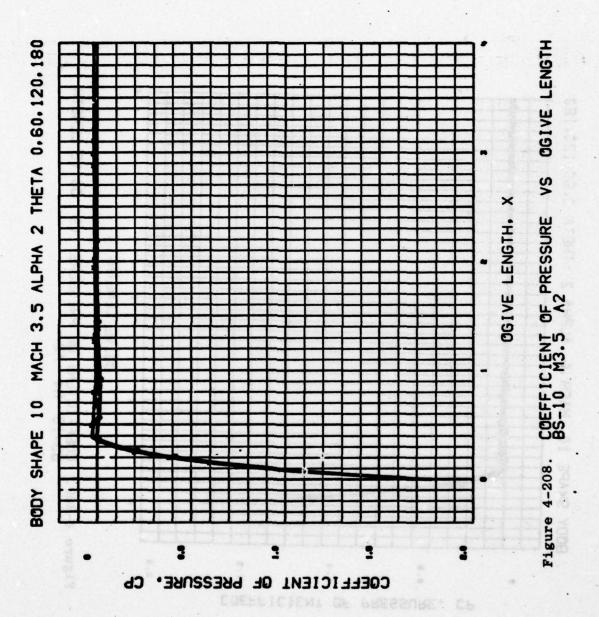
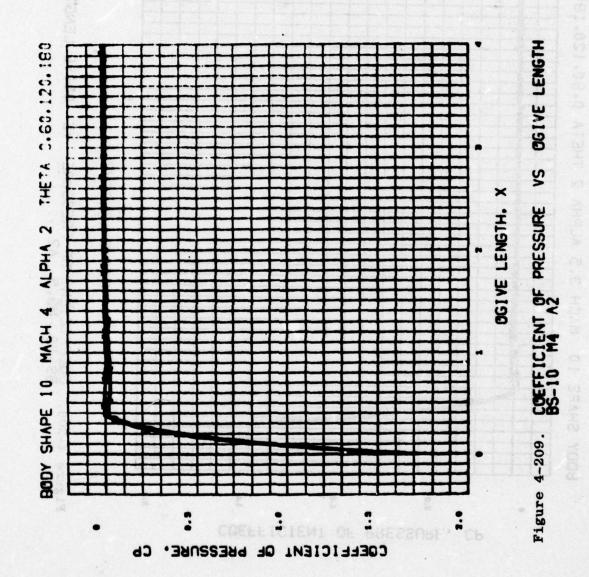
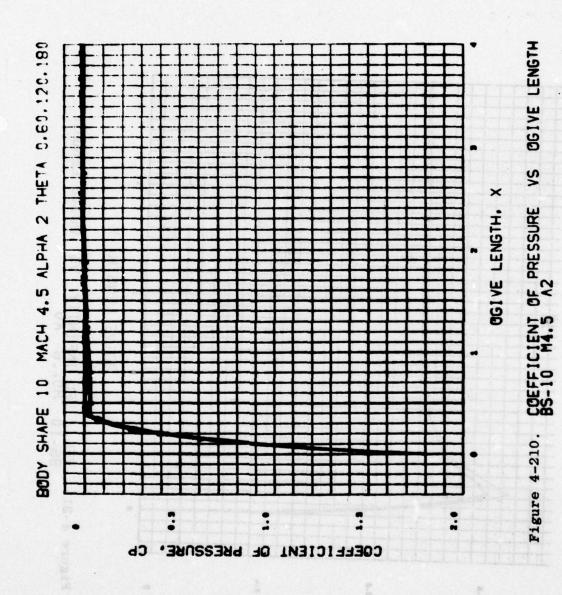


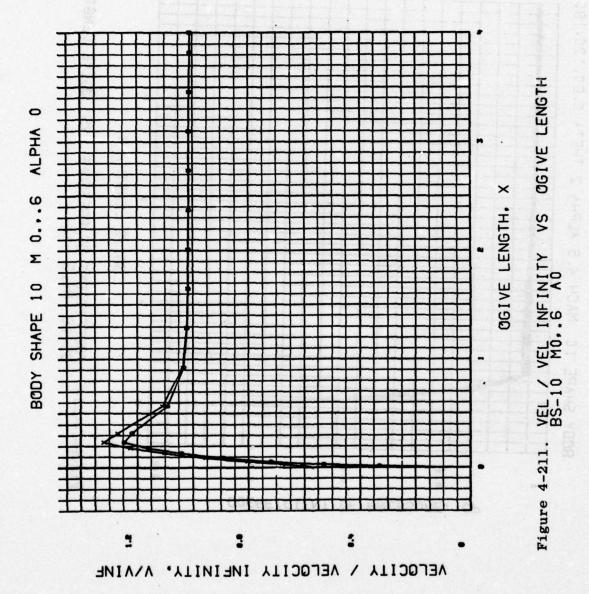
Figure 4-206. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-10 M2.5 A2











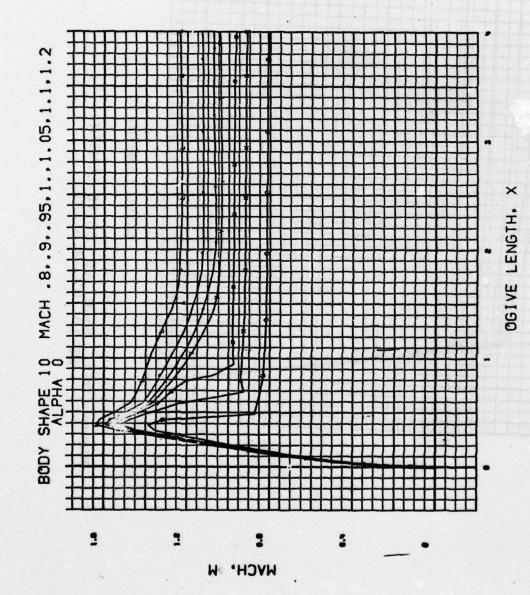


Figure 4-212. MACH VS OGIVE LENGTH BS-10 M.8-1.2 A0

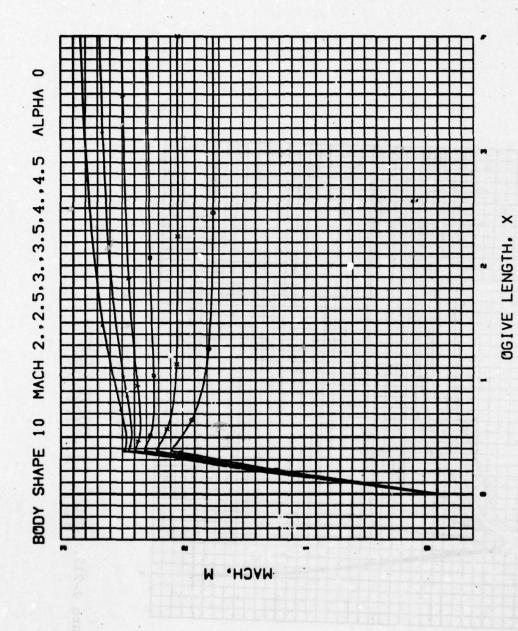


Figure 4-213, MACH VS 061VE LENGTH BS-10 M2.-4.5 A0

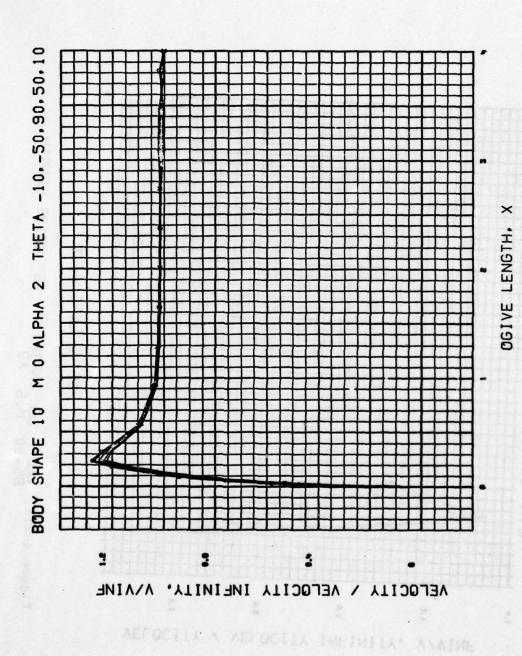


Figure 4-214. VEL / VEL INFINITY VS OGIVE LENGTH BS-10 M0 A2

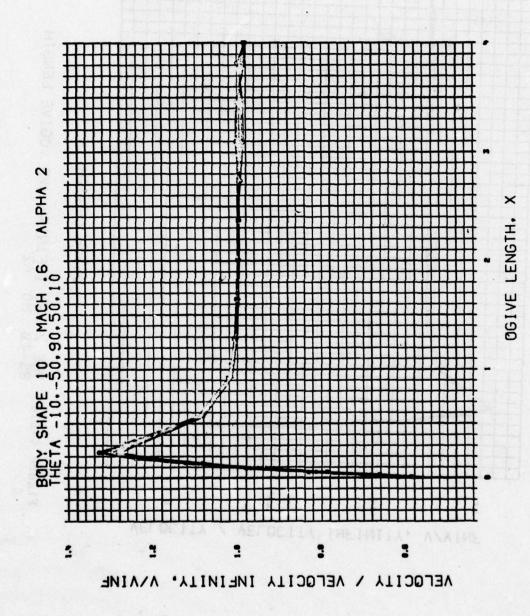


Figure 4-215. VEL / VEL INFINITY VS OGIVE LENGTH BS-10 M.6 A2

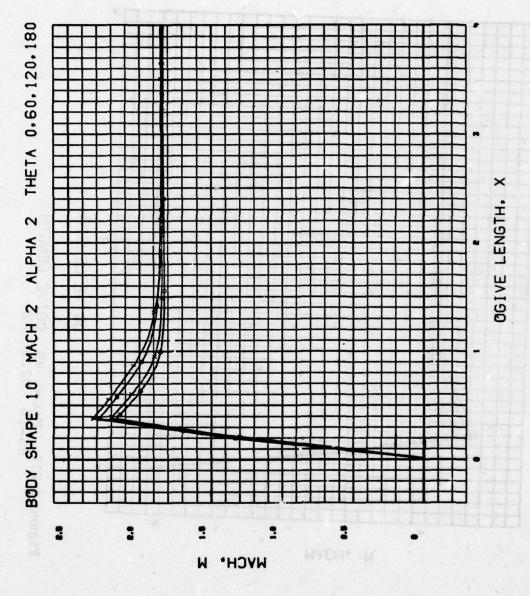


Figure 4-216. MACH VS OGIVE LENGTH BS-10 M2 A2

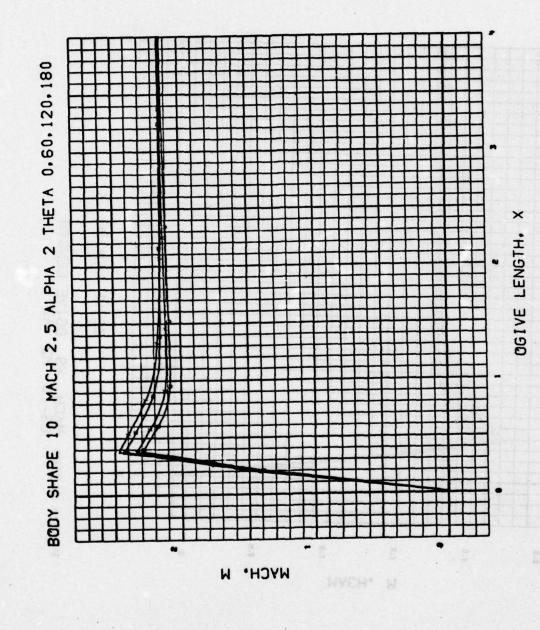


Figure 4-217. MACH VS 0GIVE LENGTH BS-10 M2.5 A2

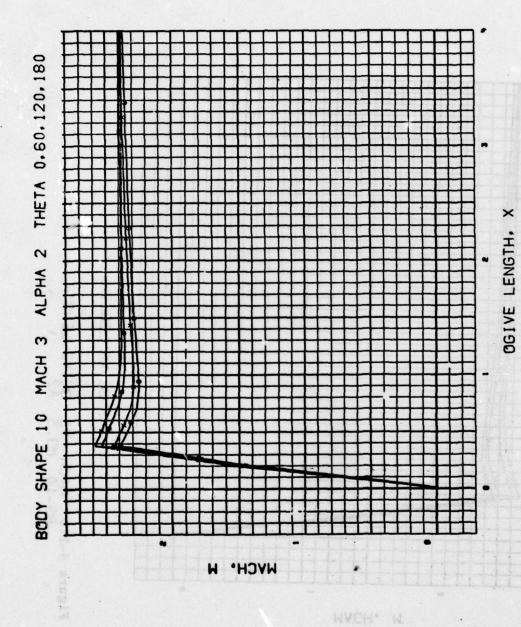


Figure 4-218. MACH VS OGIVE LENGTH BS-10 M3 A2

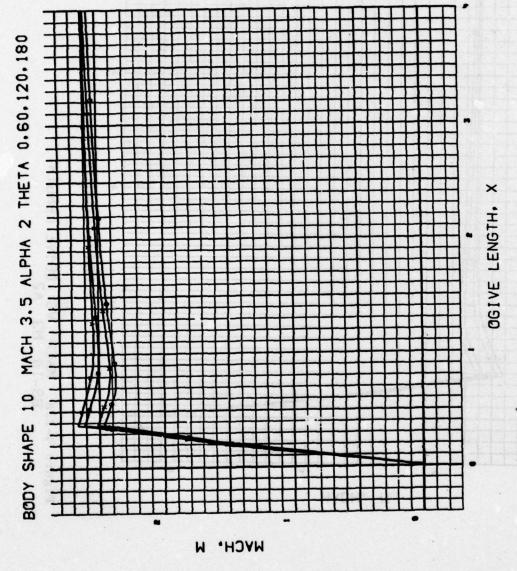


Figure 4-219. MACH VS OGIVE LENGTH BS-10 M3.5 A2

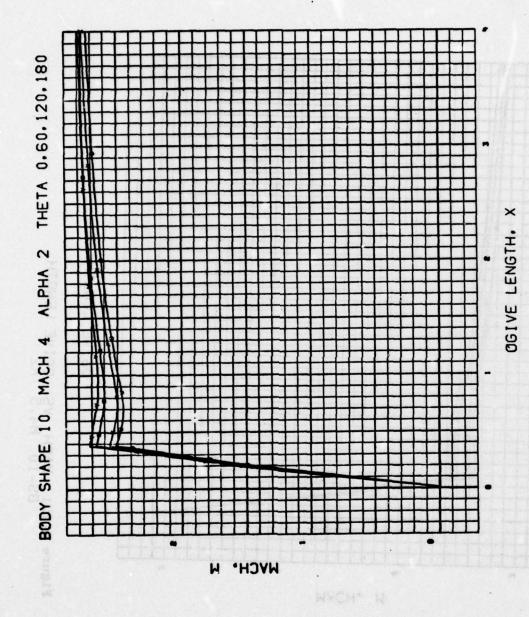


Figure 4-220. MACH VS @GIVE LENGTH BS-10 M4 A2

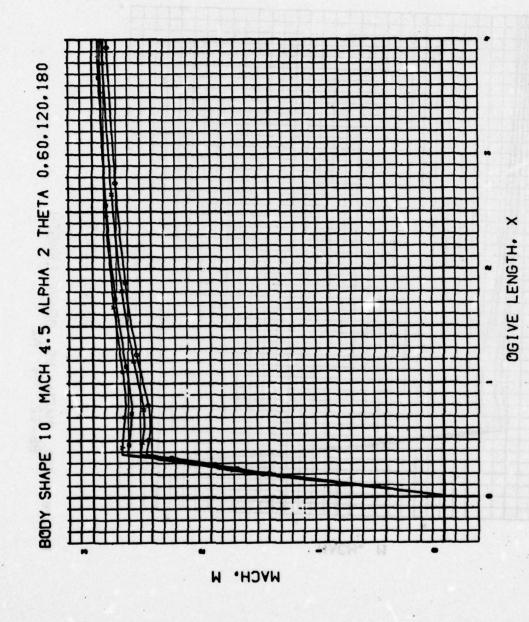
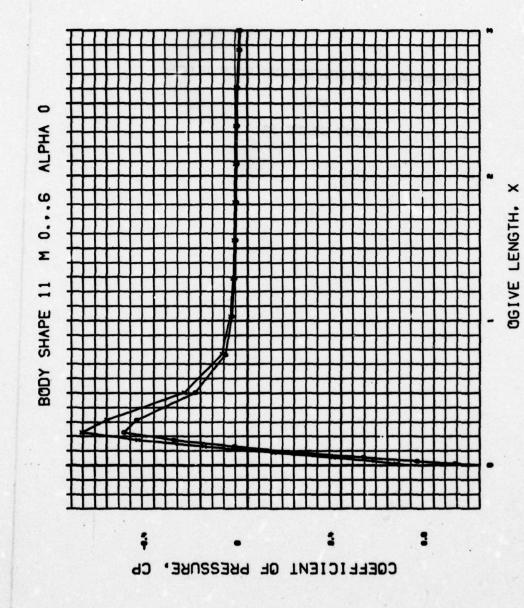
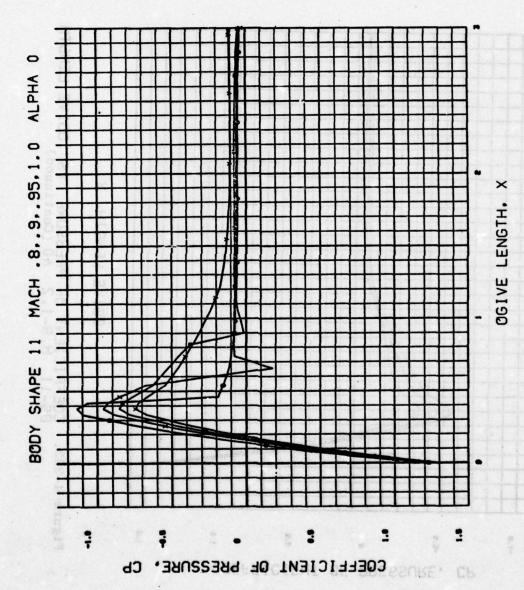


Figure 4-221. MACH VS OGIVE LENGTH BS-10 M4.5 A2

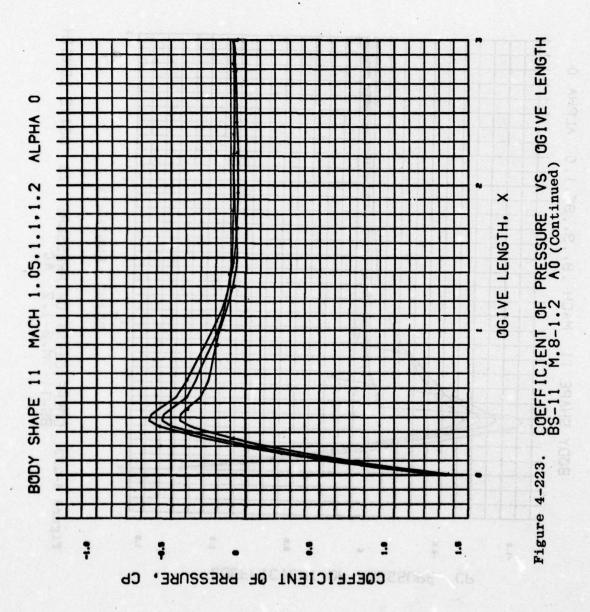
PRESSURE COEFFICIENT AND MACH PLOTS
FOR
BODY SHAPE 11



OGIVE LENGTH ۸S Figure 4-222. COEFFICIENT OF PRESSURE BS-11 M0..6 A0



OGIVE LENGTH Figure 4-223. COEFFICIENT OF PRESSURE VS BS-11 M.8-1.2 A0



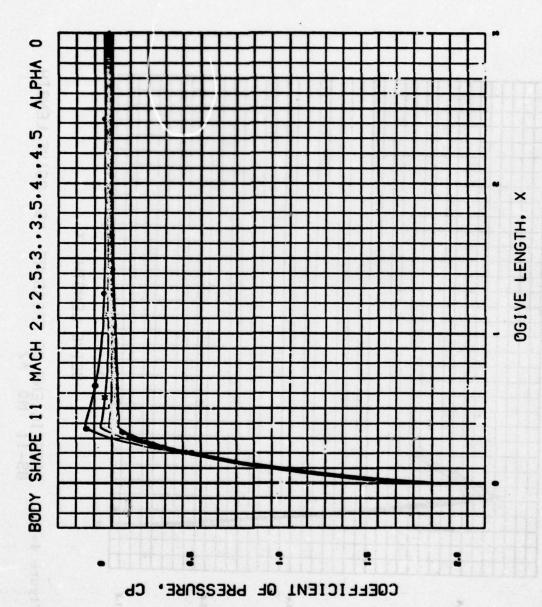
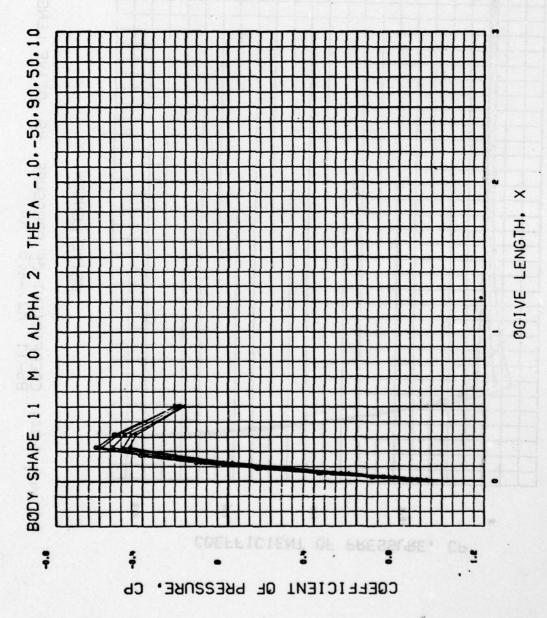


Figure 4-224. CMEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-11 M2.-4.5 A0



OGIVE LENGTH ۸S COEFFICIENT OF PRESSURE BS-11 M0 A2 Figure 4-225.

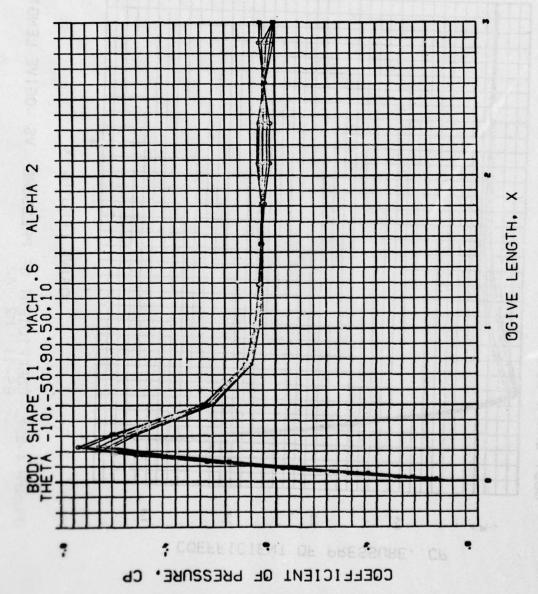


Figure 4-226. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-11 M.6 A2

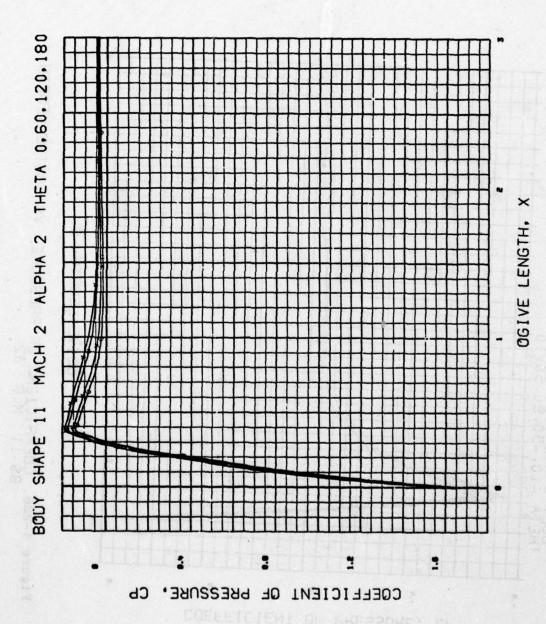
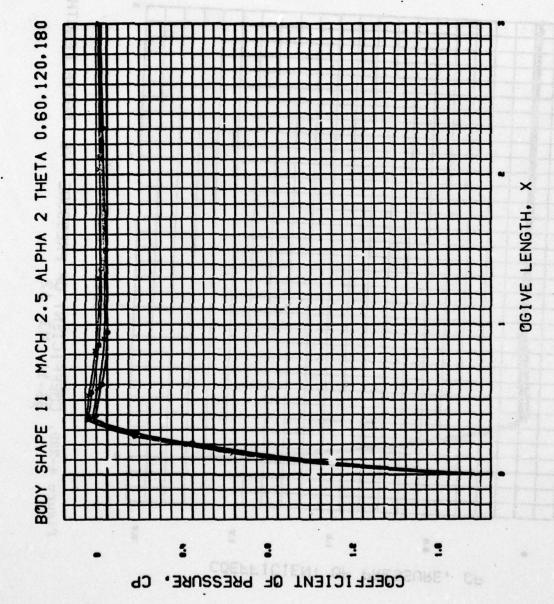
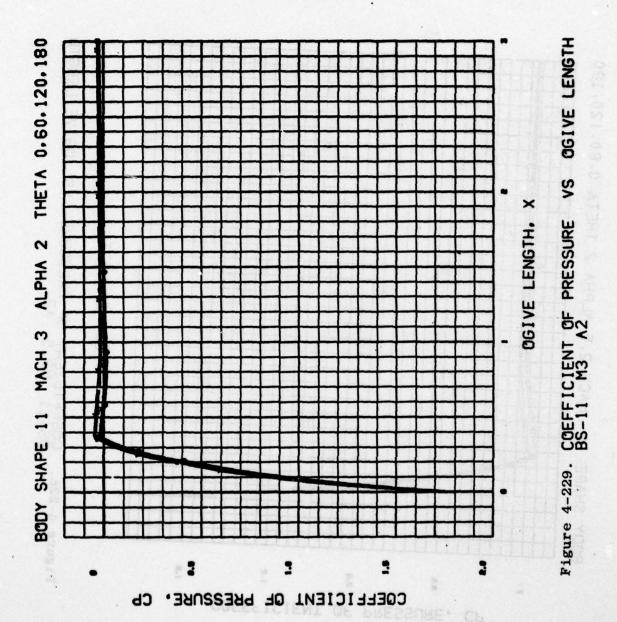
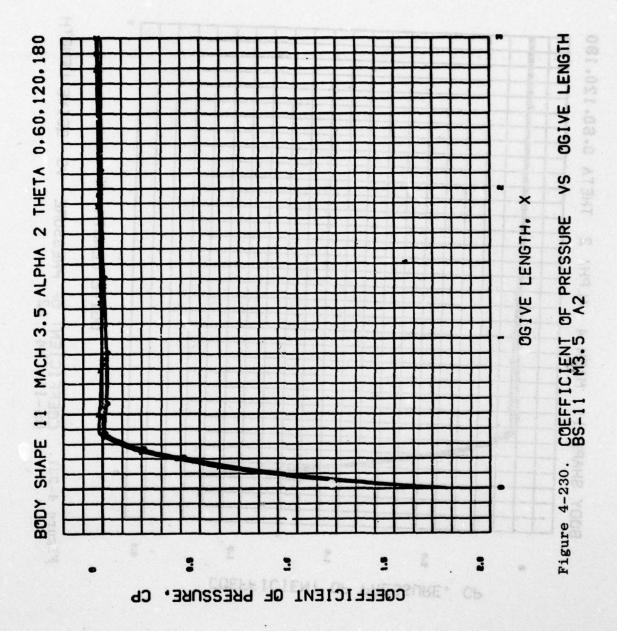


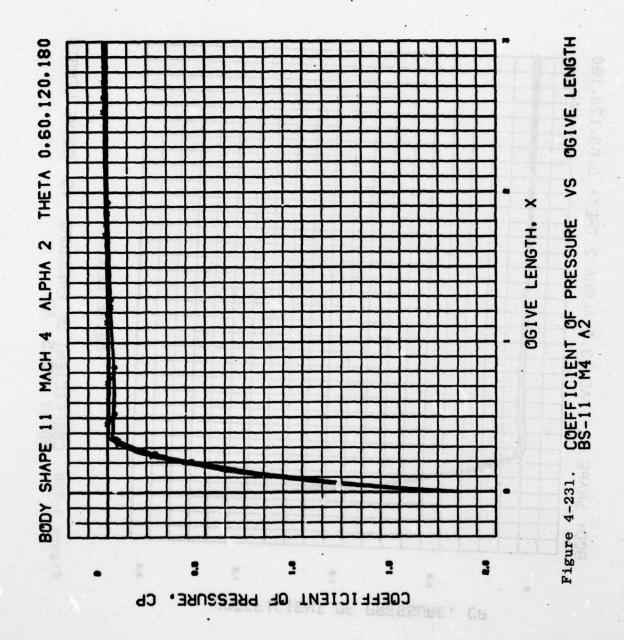
Figure 4-227. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-11 M2 A2

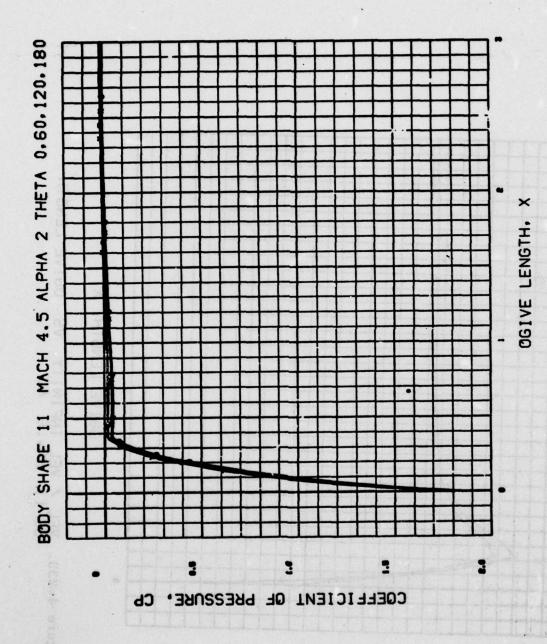


OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-11 M2.5 A2 Figure 4-228.









OGIVE LENGTH Figure 4-232. COEFFICIENT OF PRESSURE VS BS-11 M4.5 A2

VELOCITY / VELOCITY INFINITY, W/VINE

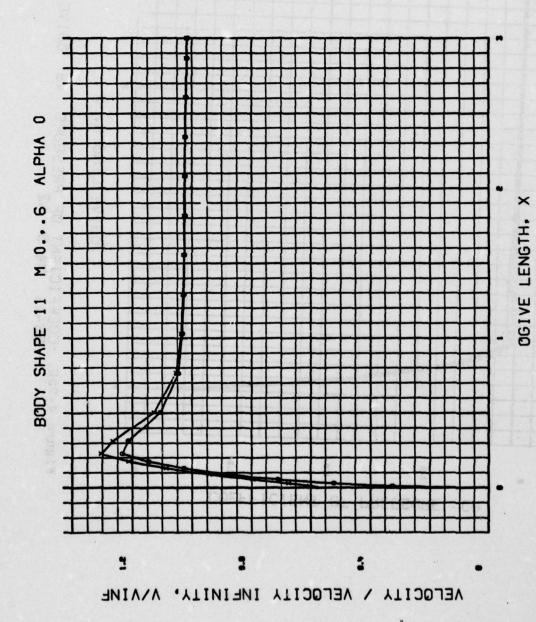


Figure 4-233. VEL / VEL INFINITY VS OGIVE LENGTH BS-11 MO..6 A0

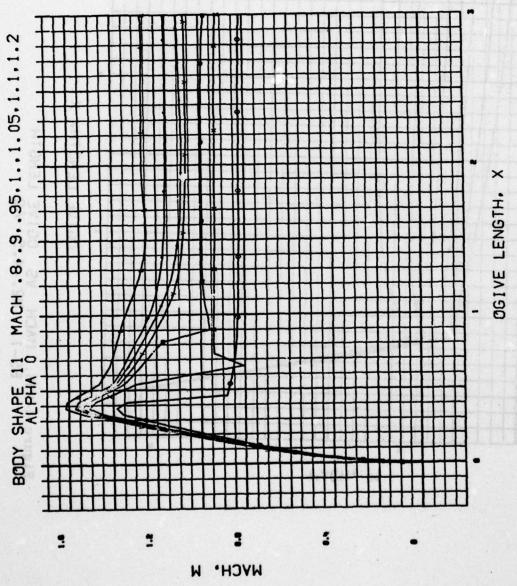


Figure 4-234. MACH VS 061VE LENGTH BS-11 M.8-1.2 A0

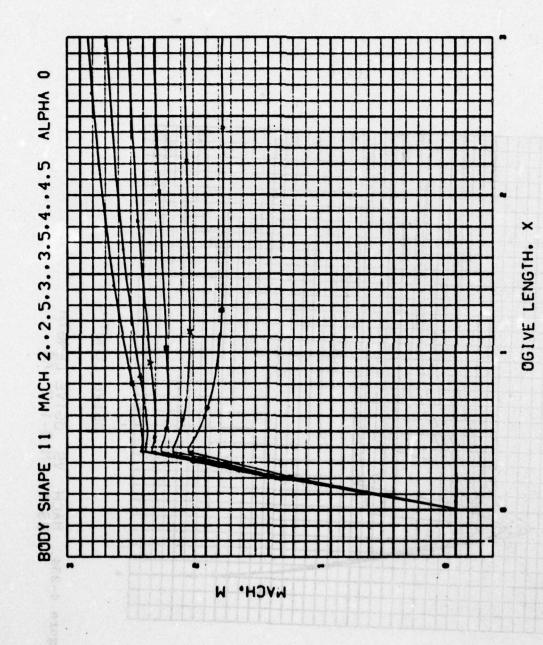


Figure 4-235. MACH VS 061VE LENGTH BS-11 M2.-4.5 A0

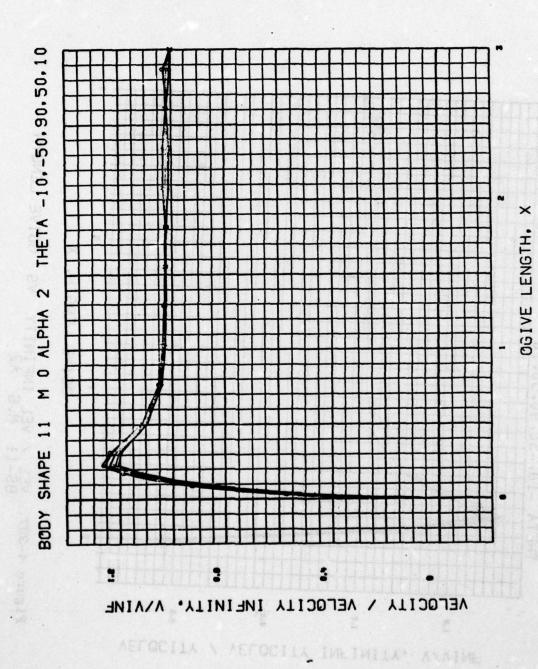


Figure 4-236. VEL / VEL INFINITY VS OGIVE LENGTH BS-11 MO A2

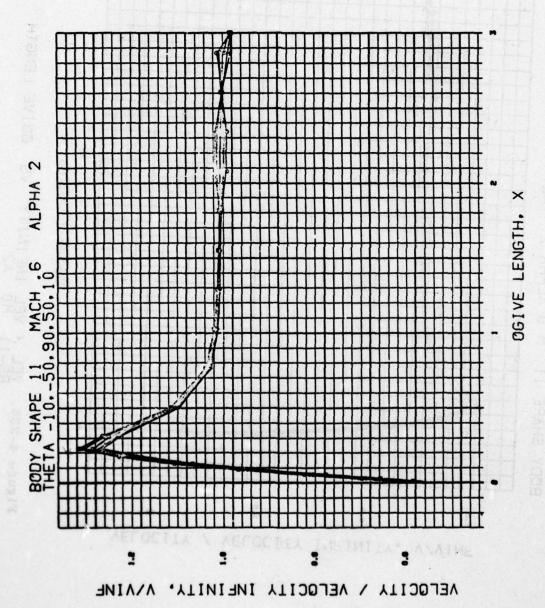


Figure 4-237. VEL / VEL INFINITY VS OGIVE LENGTH BS-11 M.6 A2

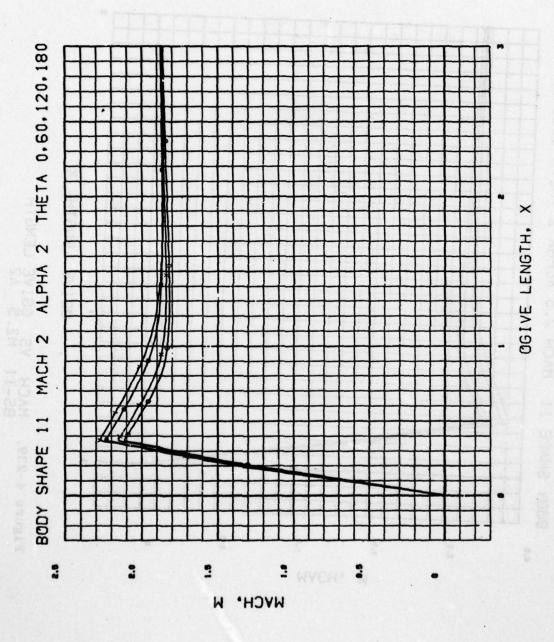


Figure 4-238. MACH VS OGIVE LENGTH BS-11 M2 A2

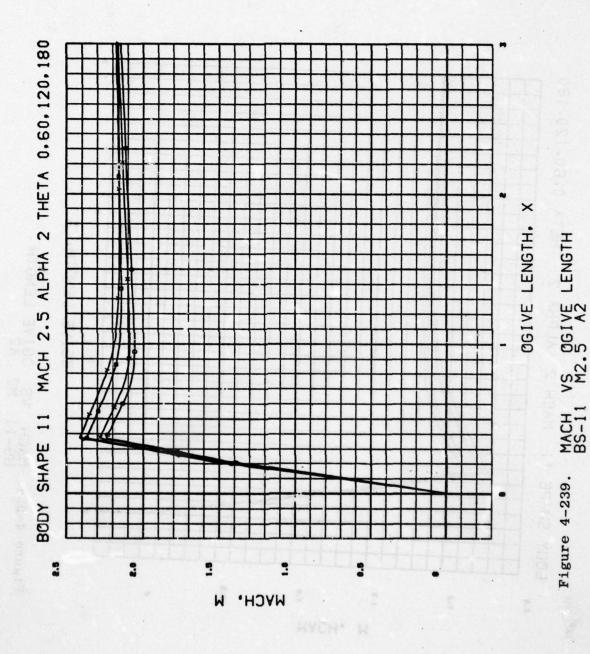
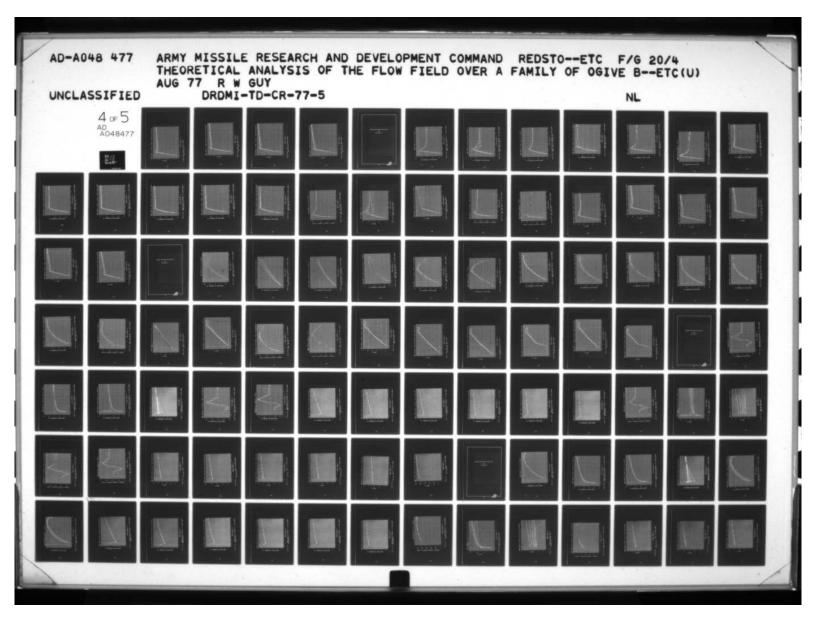
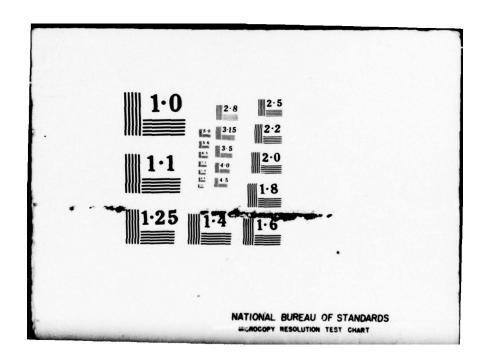


Figure 4-239.





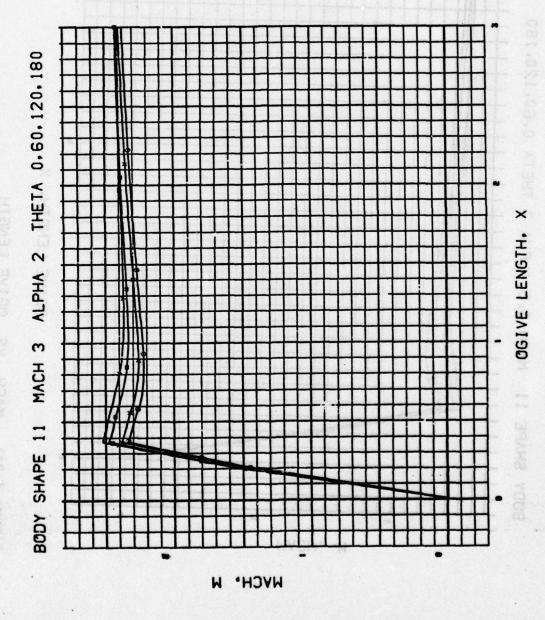


Figure 4-240. MACH VS CGIVE LENGTH BS-11 M3 A2

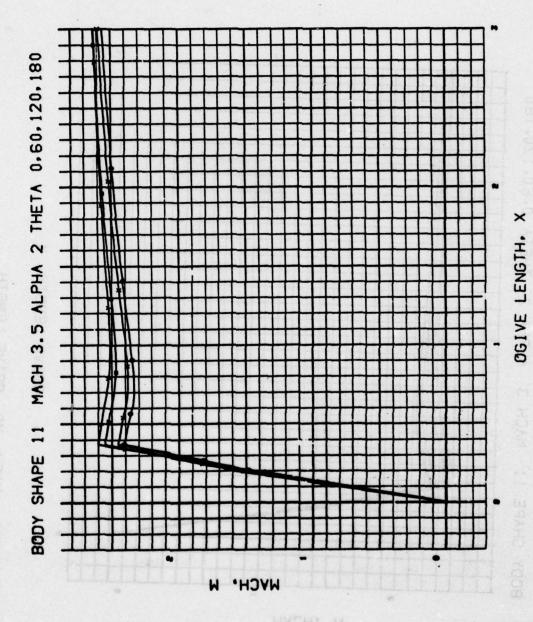


Figure 4-241. MACH VS 06IVE LENGTH BS-11 M3.5 A2

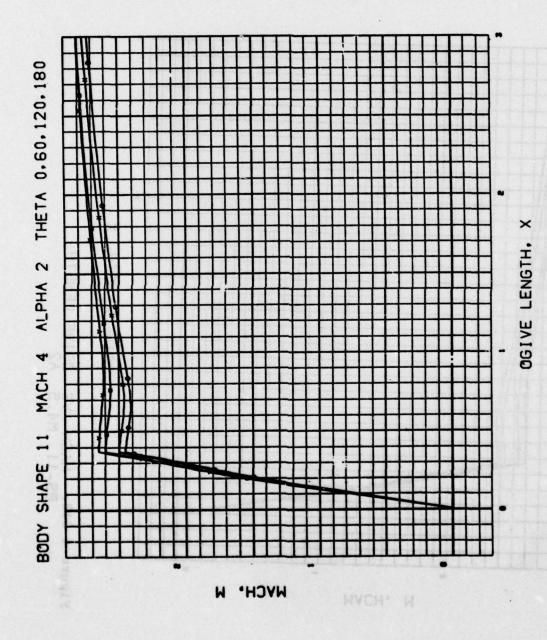
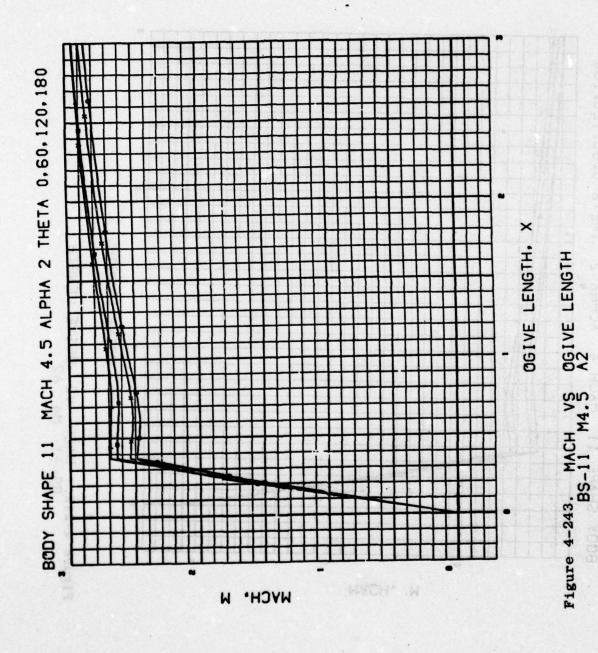


Figure 4-242. MACH VS @GIVE LENGTH BS-11 M4 A2



PRESSURE COEFFICIENT AND MACH PLOTS
FOR

BODY SHAPE 12

COEFFICIENT OF PRESSURE. CP.

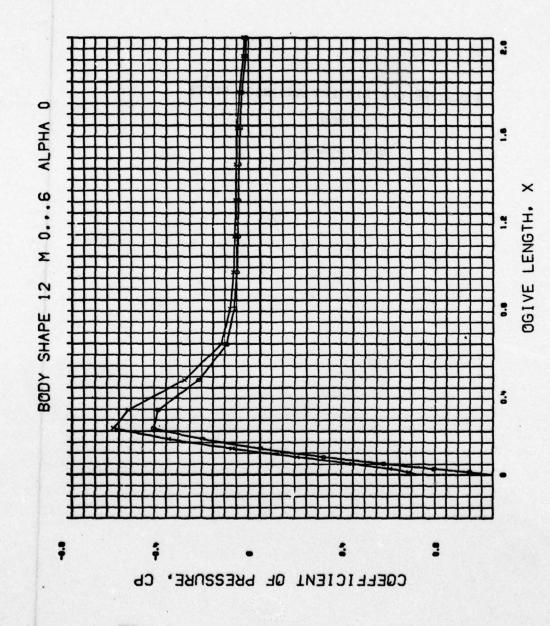


Figure 4-244. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-12 MO..6 A0

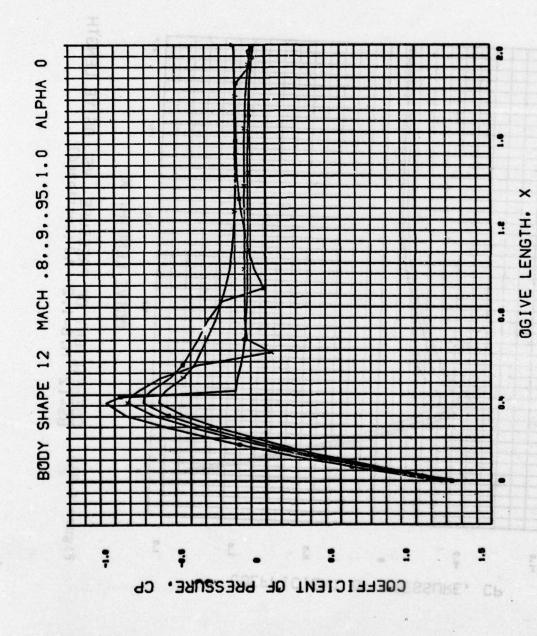
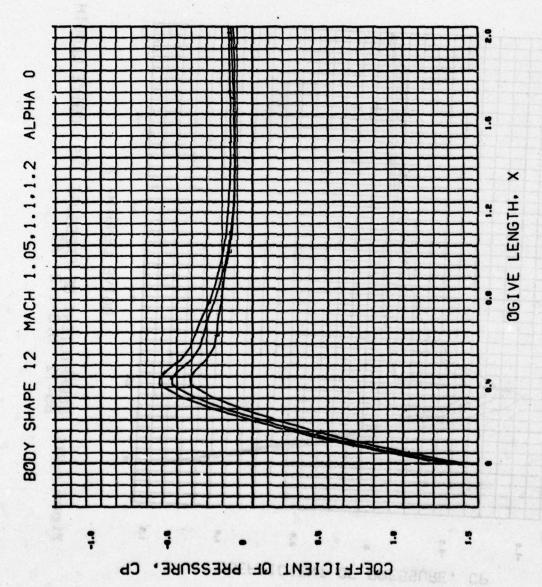
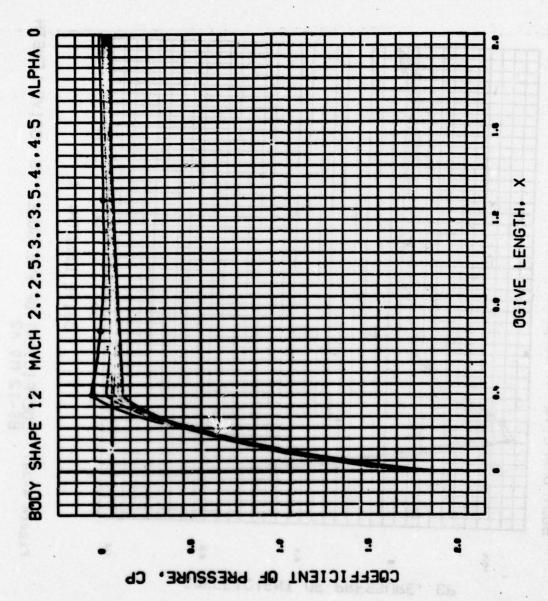


Figure 4-245. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-12 M.8-1.2 A0



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-12 M.8-1.2 A0 (Continued) Figure 4-245.



OGIVE LENGTH Figure 4-246. COEFFICIENT OF PRESSURE VS BS-12 M2.-4.5 A0

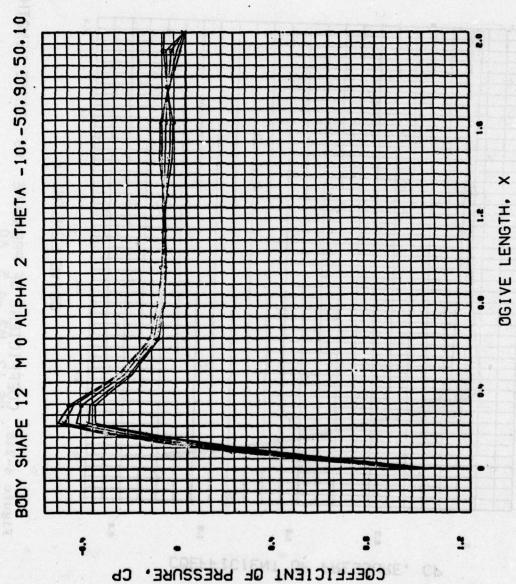
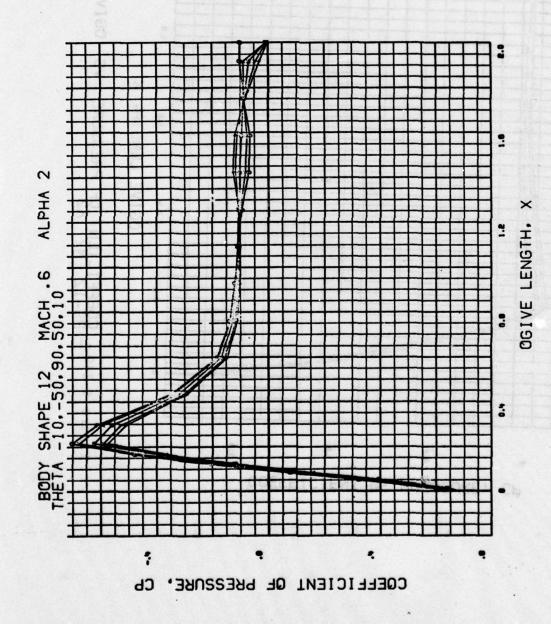


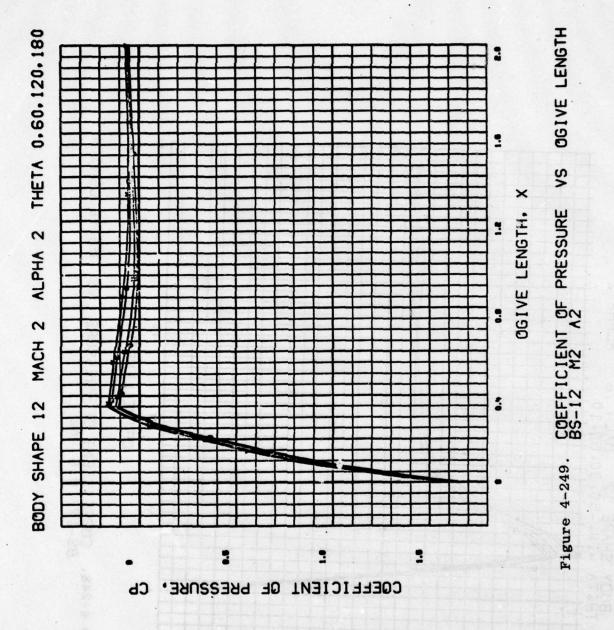
Figure 4-247. COEFFICIENT OF PRESSURE BS-12 M0 A2

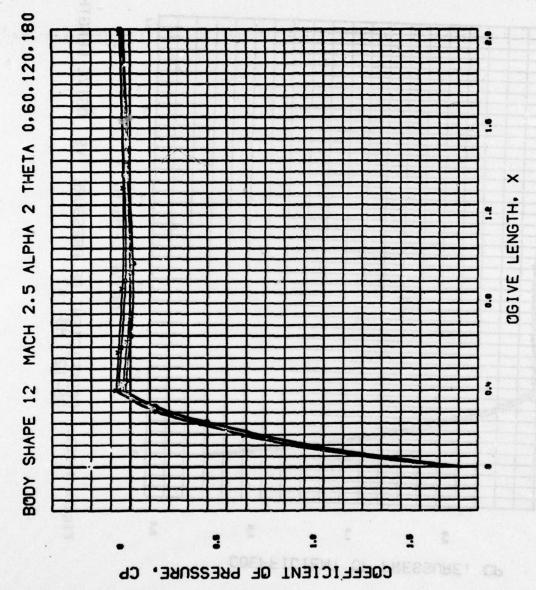
OGIVE LENGTH

٧S

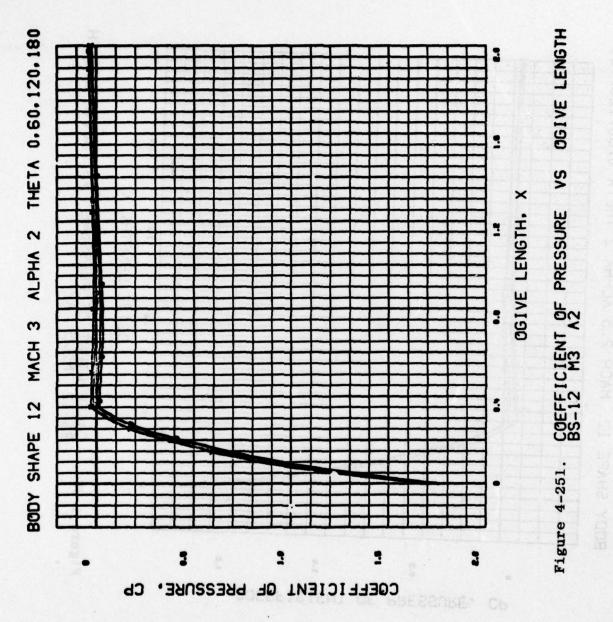


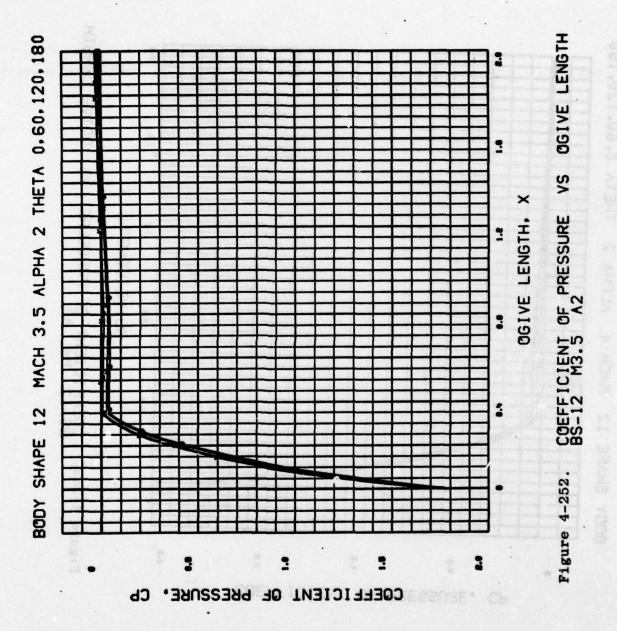
OGIVE LENGTH ۸S Figure 4-248. COEFFICIENT OF PRESSURE BS-12 M.6 A2

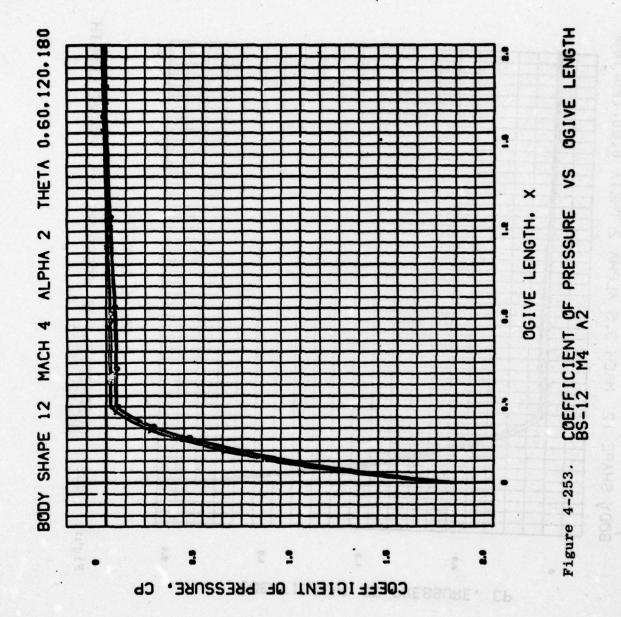


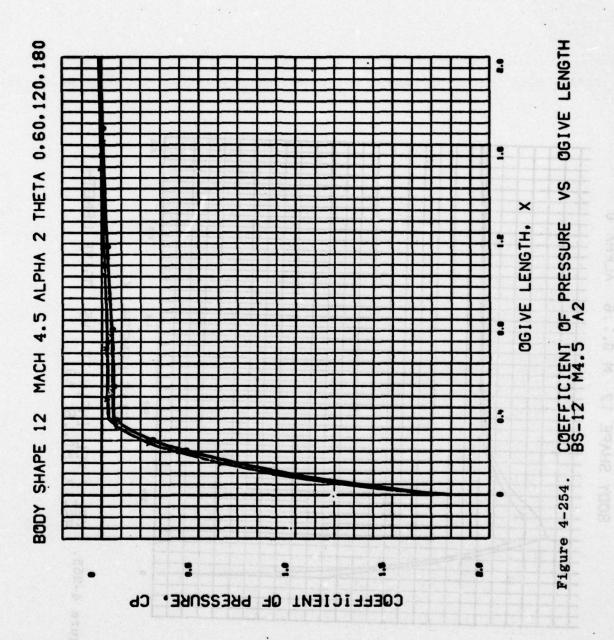


OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-12 M2.5 A2 Figure 4-250.

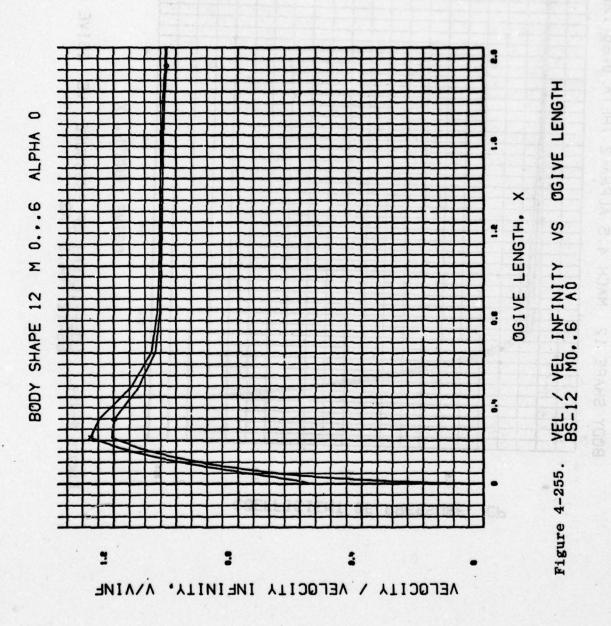








VELOCITY / VELOCITY INFINITY, V/VINF



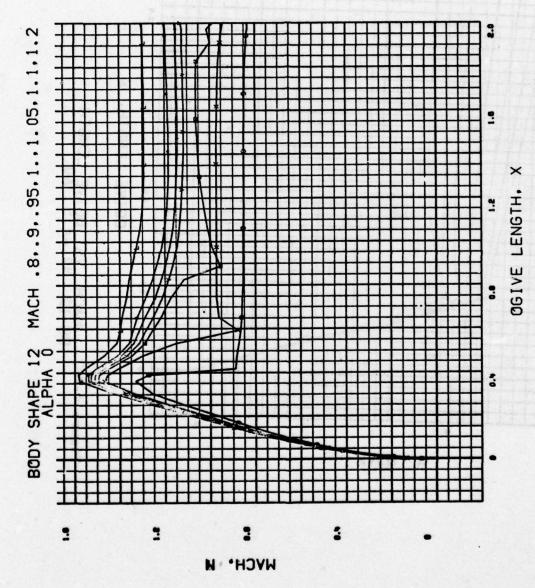


Figure 4-256. MACH VS 0GIVE LENGTH BS-12 M.8-1.2 A0

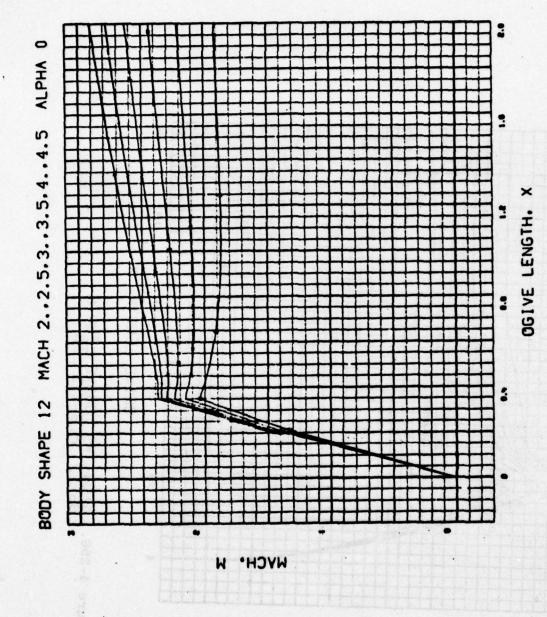


Figure 4-257. MACH VS 061VE LENGTH 85-12 M2.-4.5 A0

296

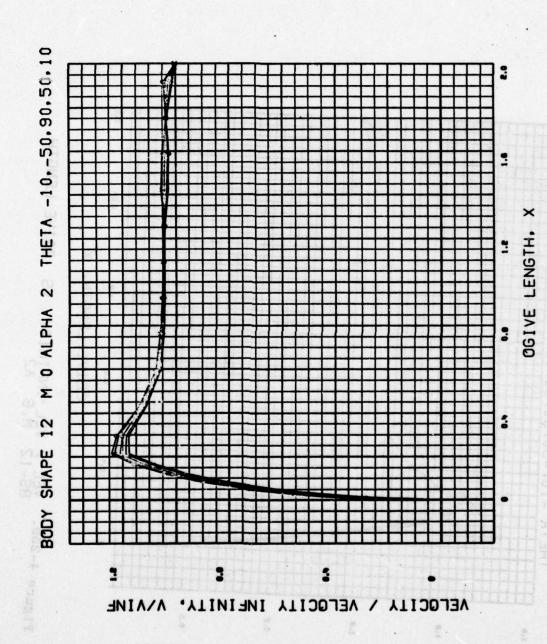
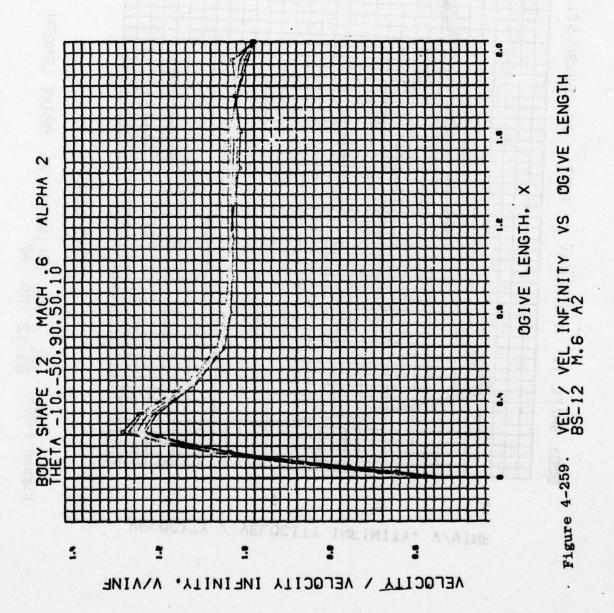


Figure 4-258. VEL / VEL INFINITY VS OGIVE LENGTH BS-12 M0 A2



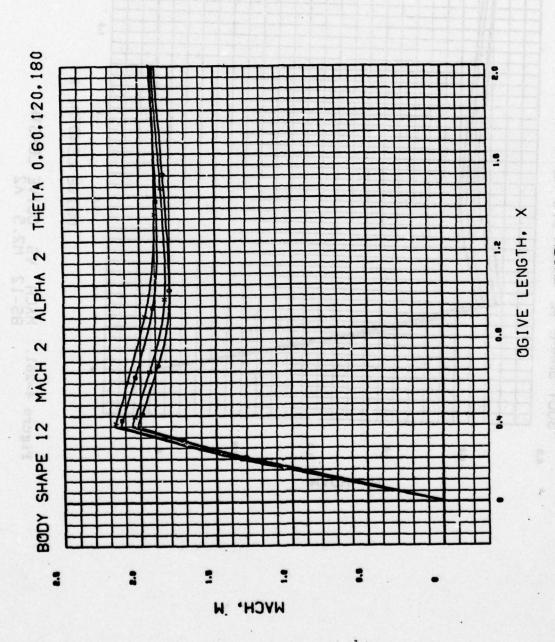


Figure 4-260, MACH VS UGIVE LENGTH BS-12 M2 A2

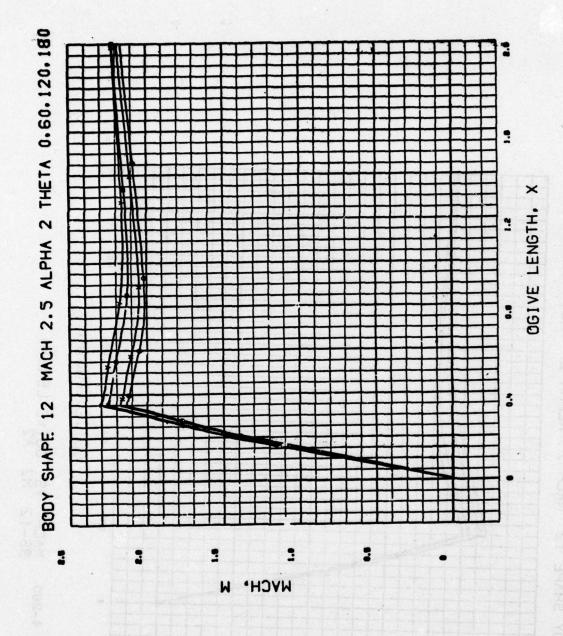


Figure 4-261. MACH VS 061VE LENGTH BS-12 M2.5 A2

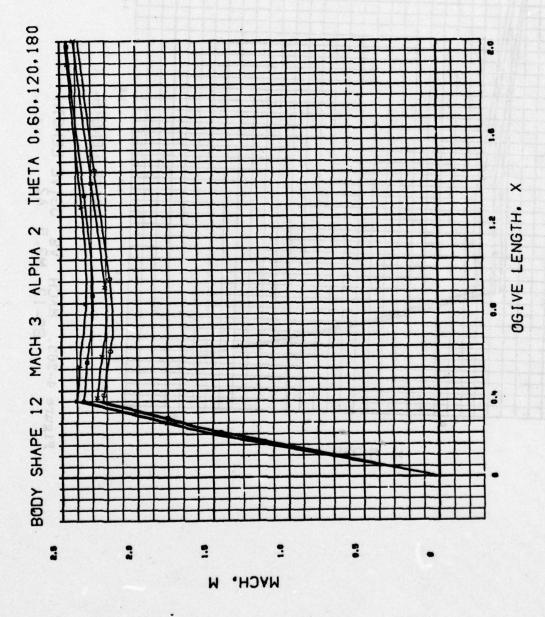
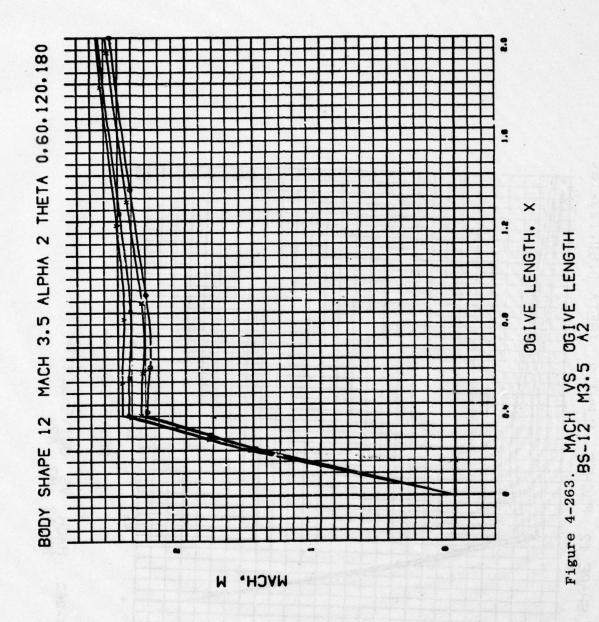


Figure 4-262. MACH VS OGIVE LENGTH SS-12 M3 A2



MACH. M

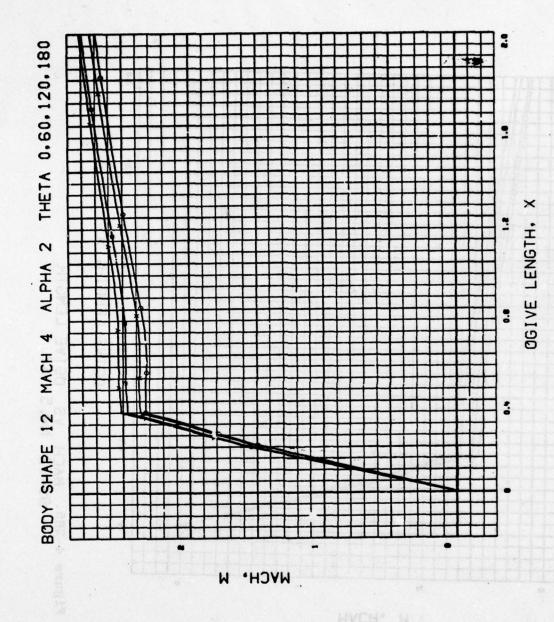
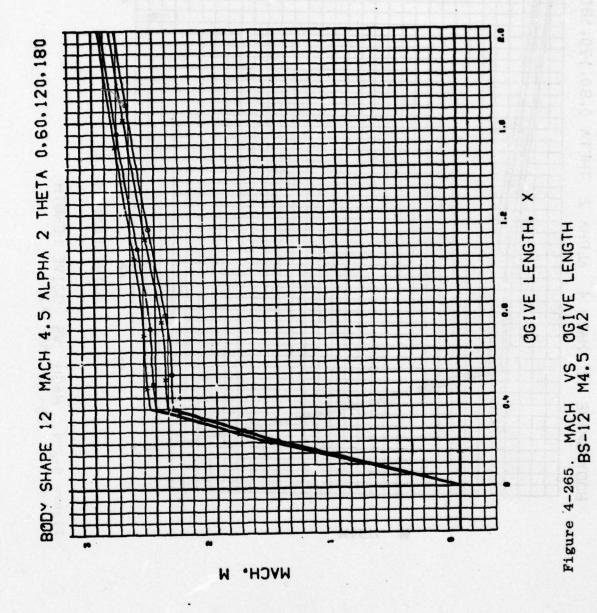


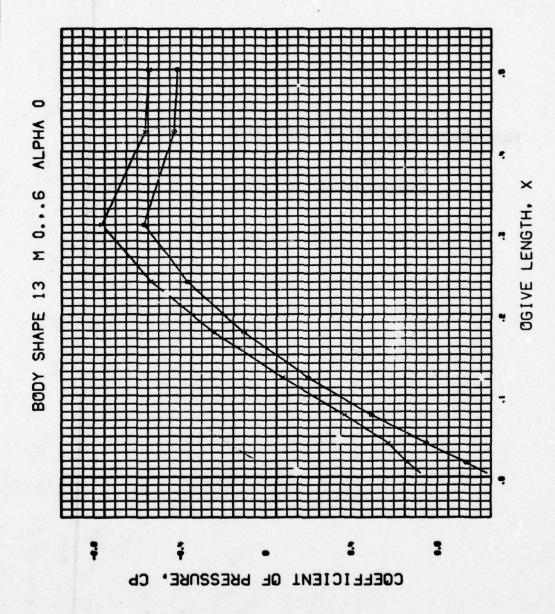
Figure 4-264. MACH VS 0GIVE LENGTH BS-12 M4 A2



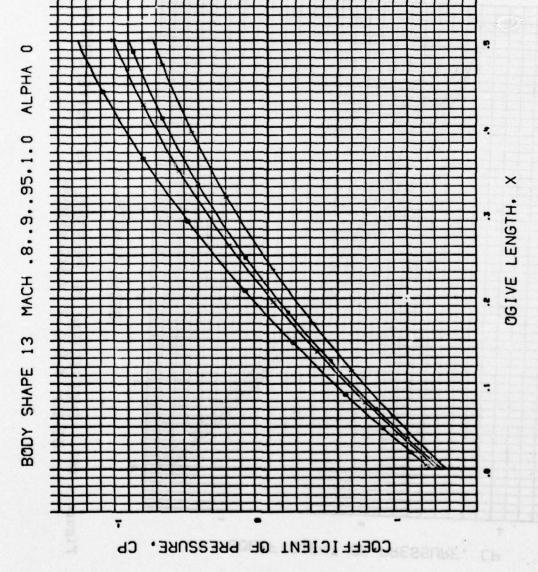
PRESSURE COEFFICIENT AND MACH PLOTS

FOR

BODY SHAPE 13



OGIVE LENGTH ۸S COEFFICIENT OF PRESSURE BS-13 MO..6 A0 Figure 4-266.



VS OGIVE LENGTH Figure 4-267. COEFFICIENT OF PRESSURE BS-13 M.8-1.2 A0

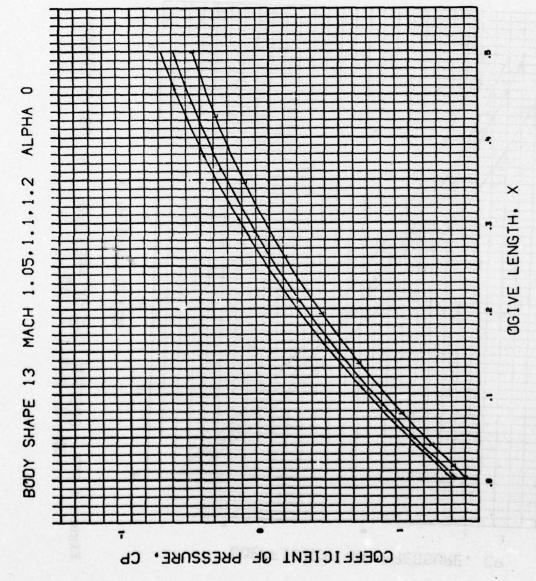
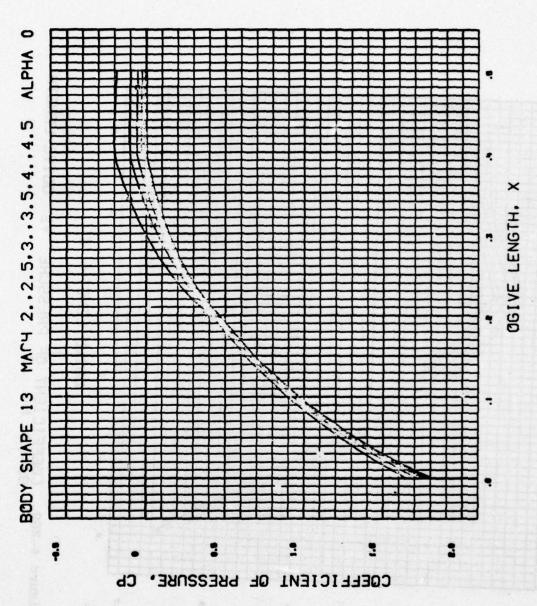


Figure 4-267. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-13 M.8-1.2 A0 (Continued)



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-13 M2.-4.5 A0 Figure 4-268

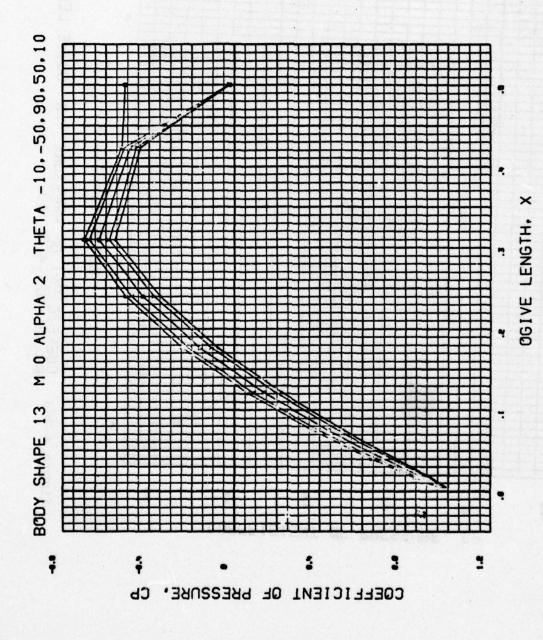


Figure 4-269. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-13 MO A2

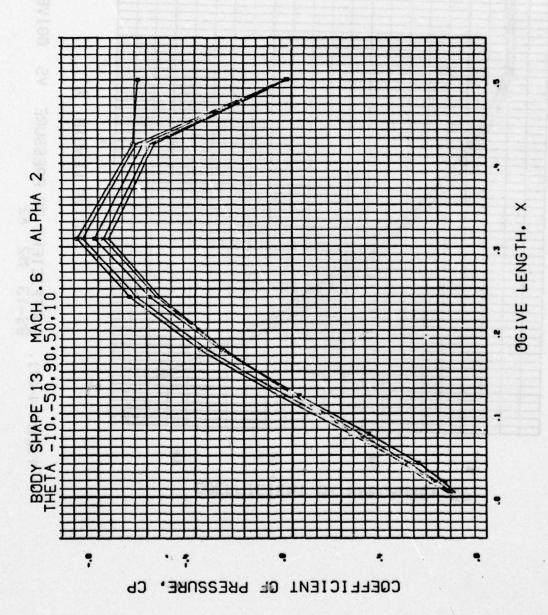


Figure 4-270. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-13 M.6 A2

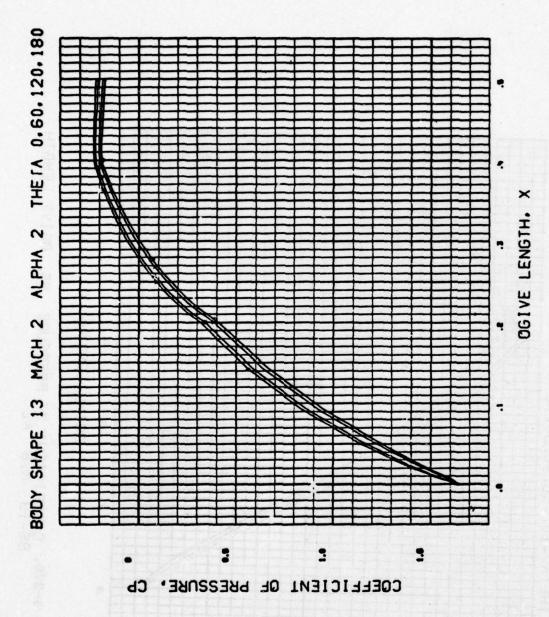
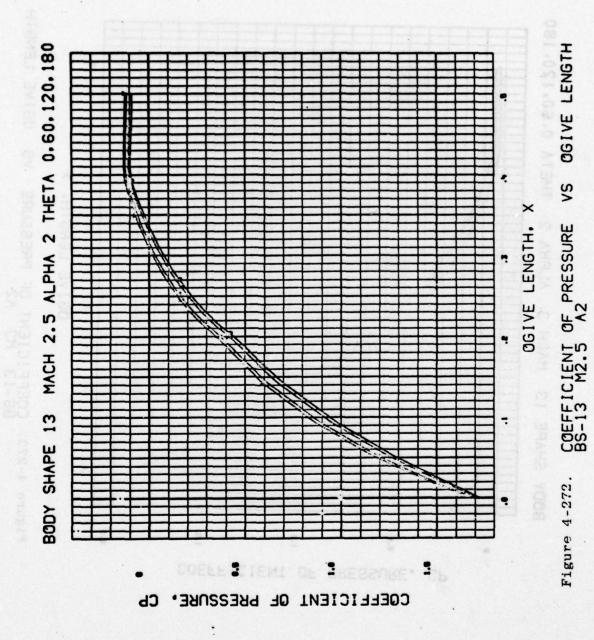
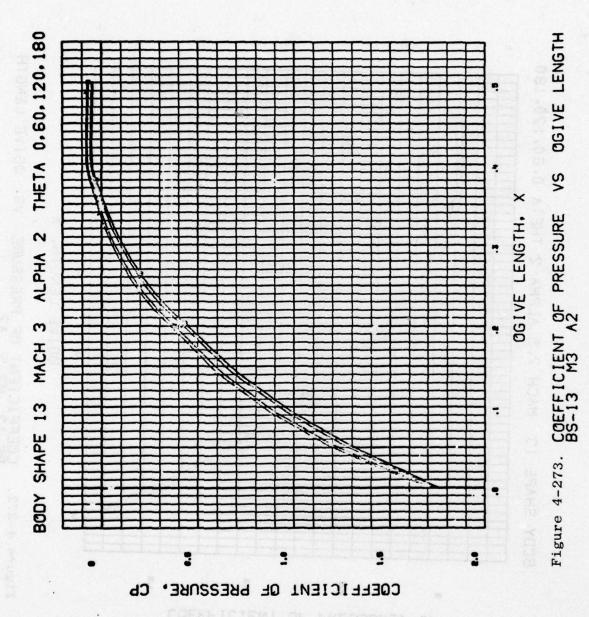
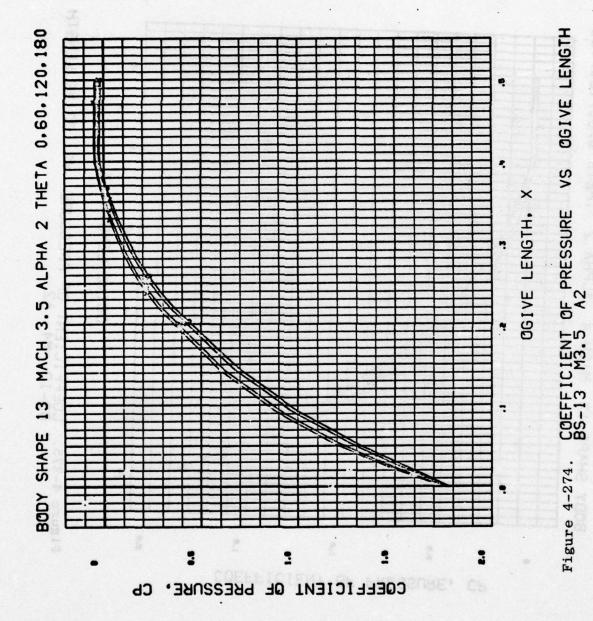
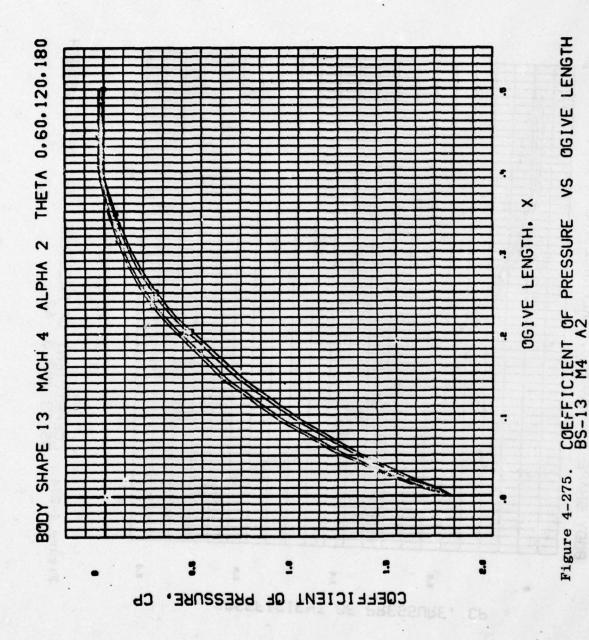


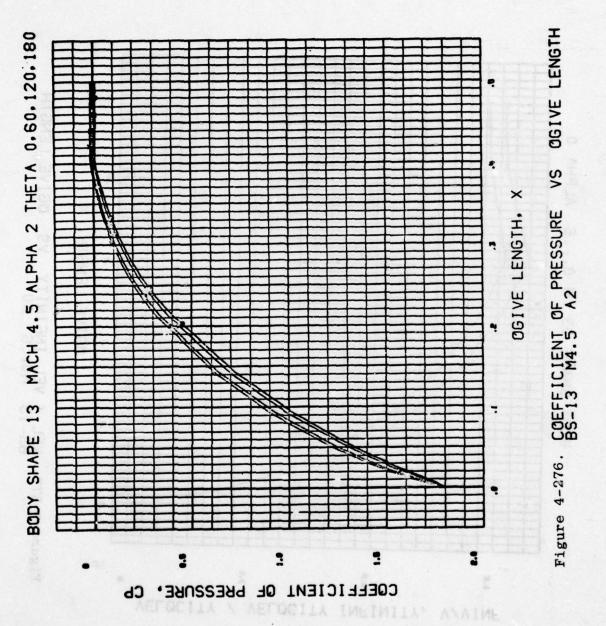
Figure 4-271. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-13 M2 A2











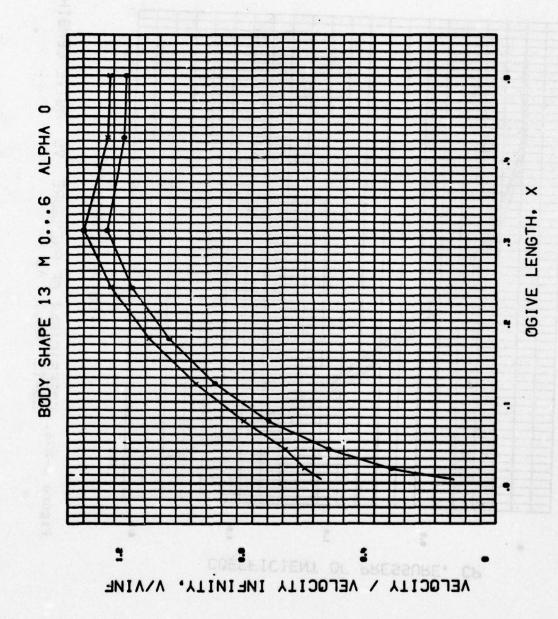


Figure 4-277. VEL / VEL INFINITY VS OGIVE LENGTH BS-13 MO..6 A0

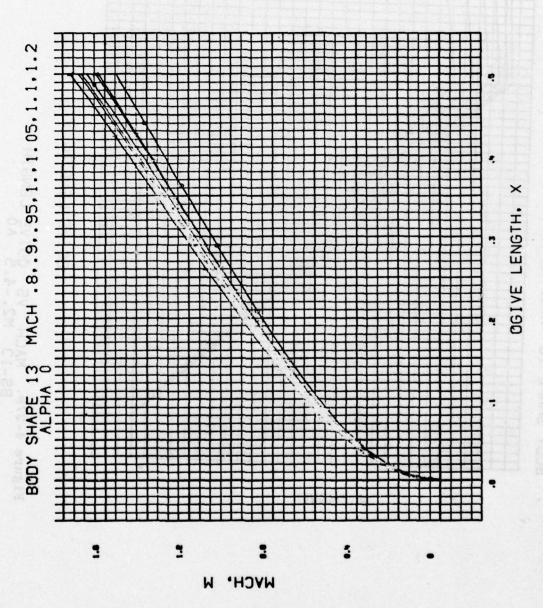


Figure 4-278. MACH VS 06IVE LENGTH 85-13 M.8-1.2 A0

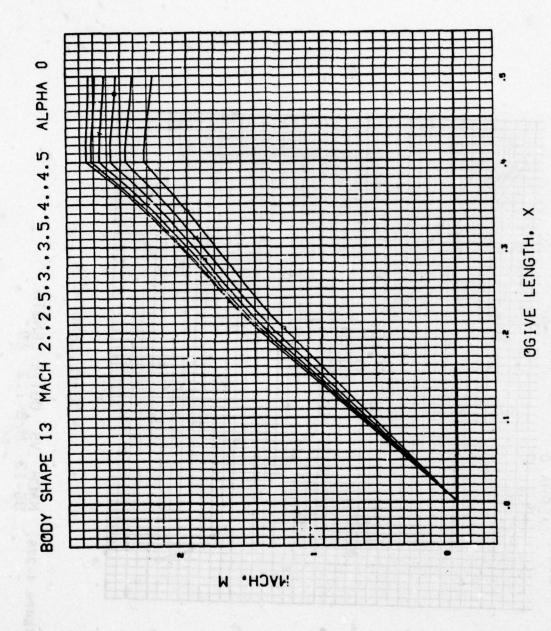


Figure 4-279. MACH VS 061VE LENGTH BS-13 M2.-4.5 A0

320

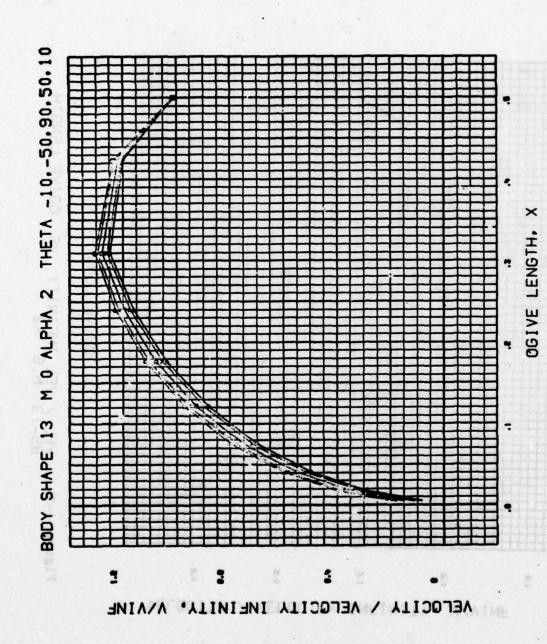


Figure 4-280. VEL / VEL INFINITY VS OGIVE LENGTH BS-13 M0 A2

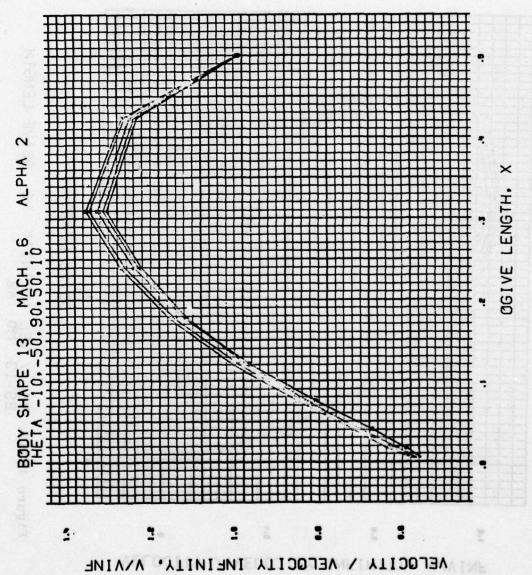


Figure 4-281. VEL / VEL INFINITY VS OGIVE LENGTH BS-13 M.6 A2

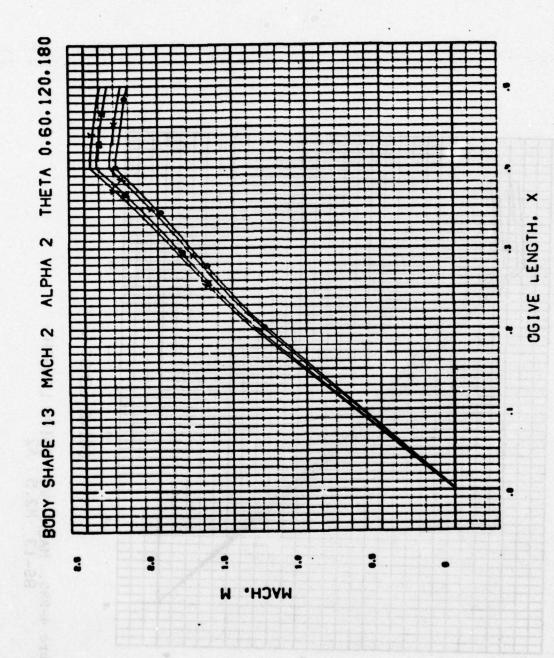


Figure 4-282. MACH VS OGIVE LENGTH BS-13 M2 A2

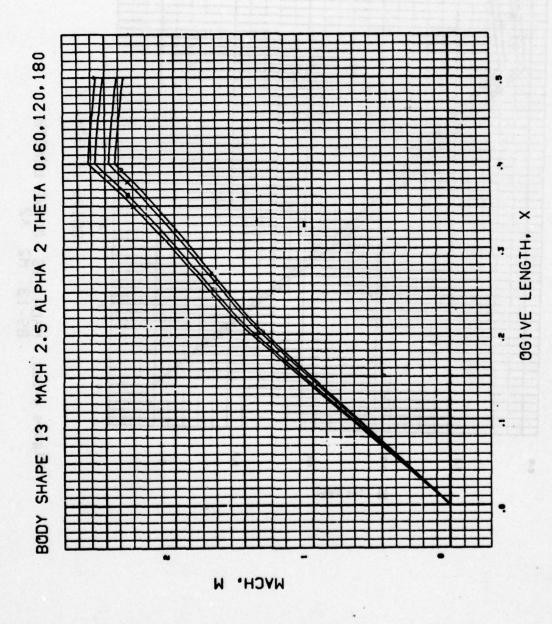


Figure 4-283. MACH VS 0GIVE LENGTH BS-13 M2.5 A2

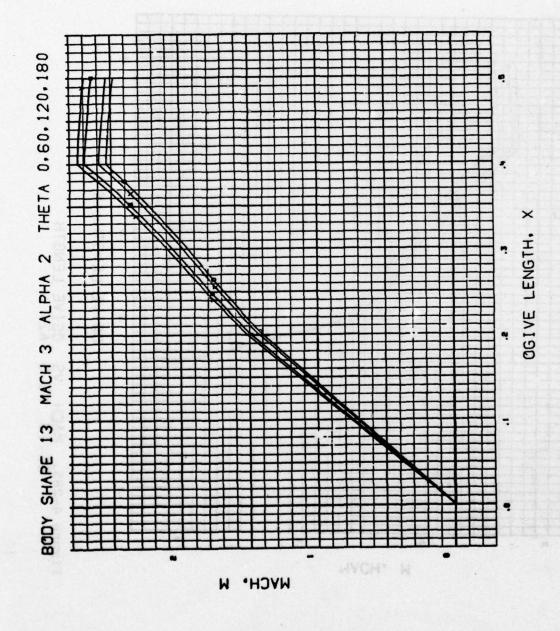


Figure 4-284, MACH VS OGIVE LENGTH BS-13 M3 A2

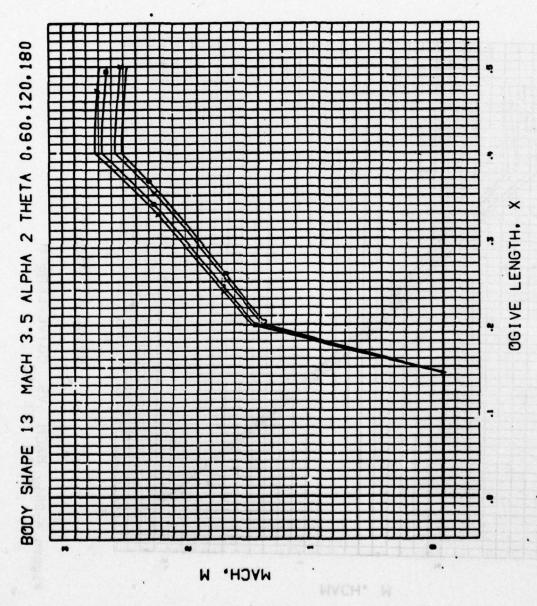


Figure 4-285. MACH VS 06IVE LENGTH BS-13 M3.5 A2

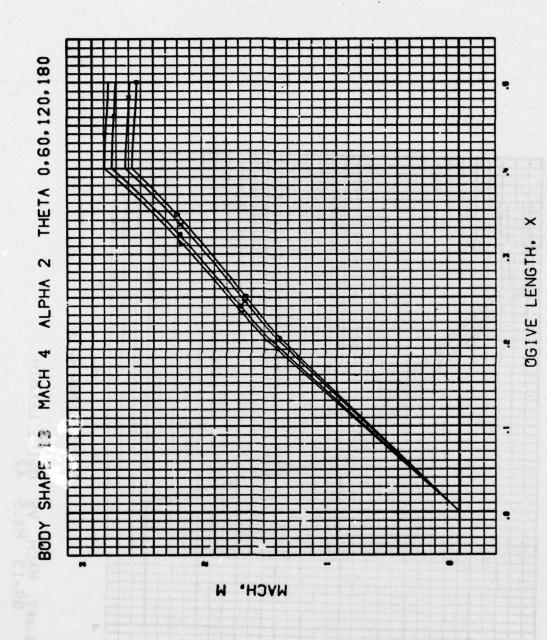


Figure 4-286. MACH VS OGIVE LENGTH BS-13 M4 A2

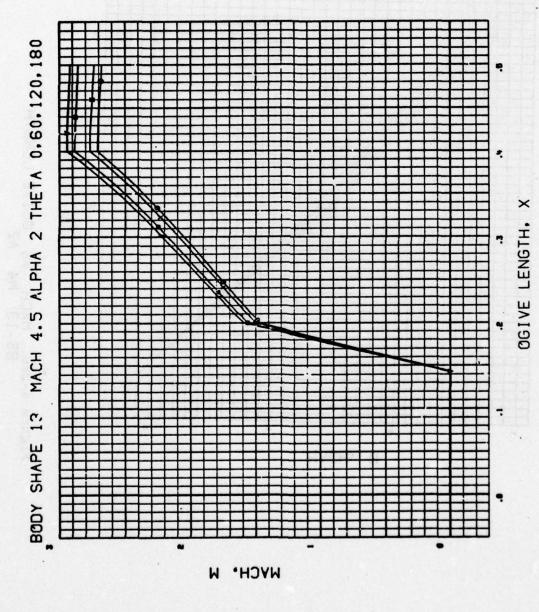
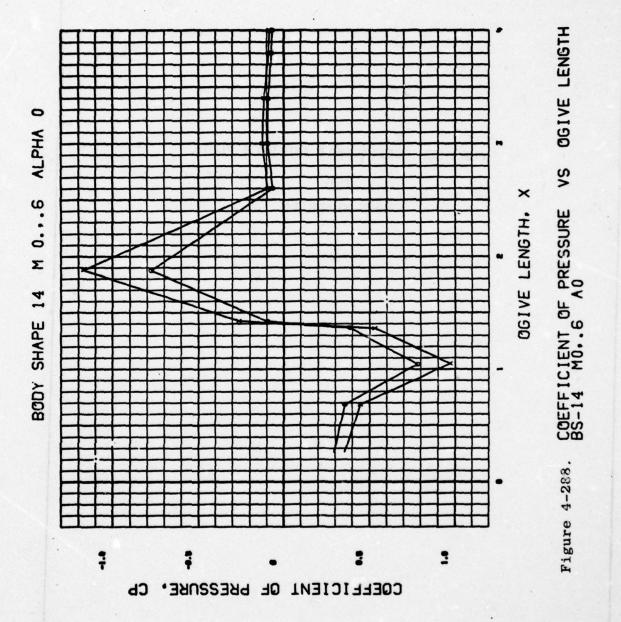


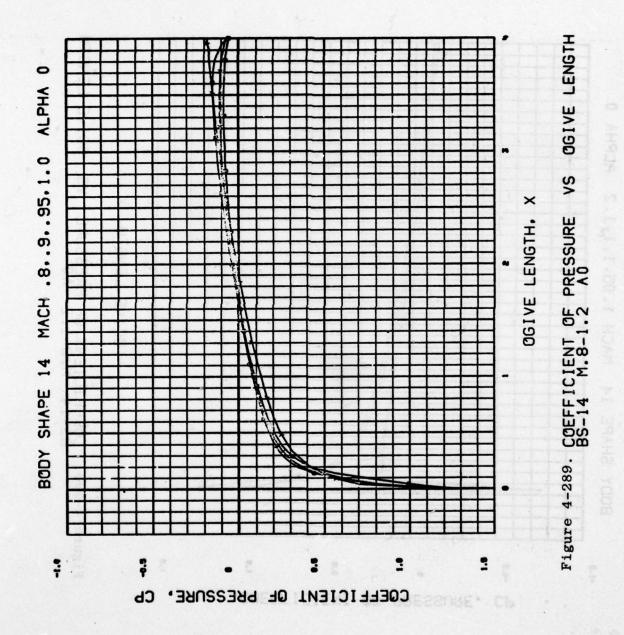
Figure 4-287, MACH VS 06IVE LENGTH BS-13 M4.5 A2

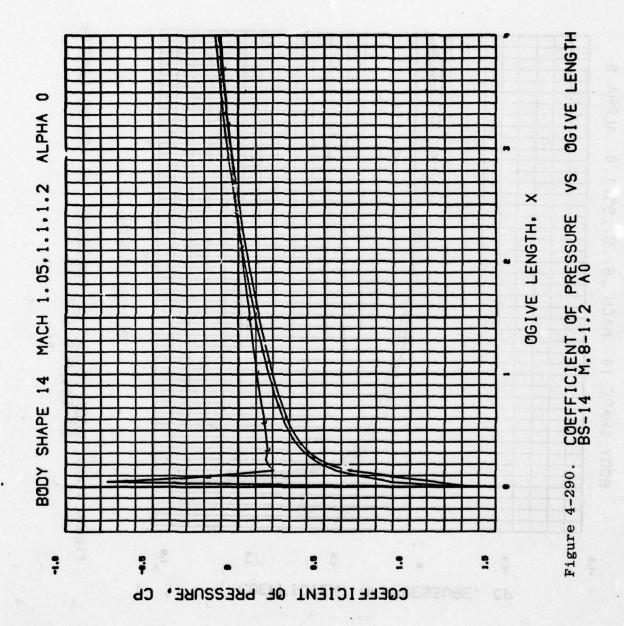
PRESSURE COEFFICIENT AND MACH PLOTS

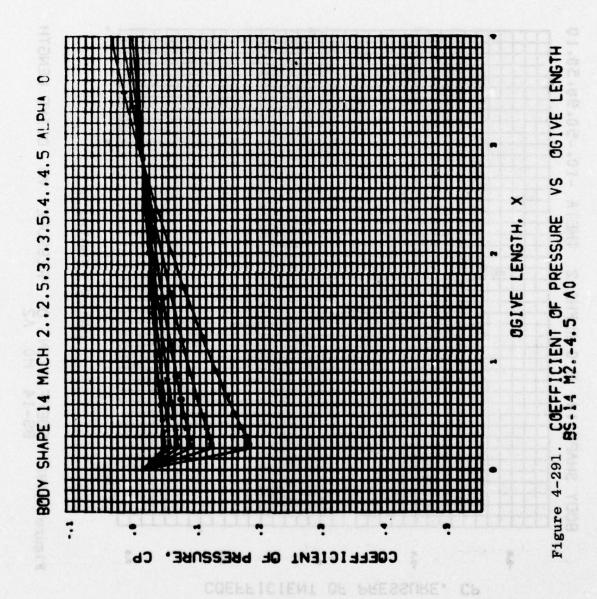
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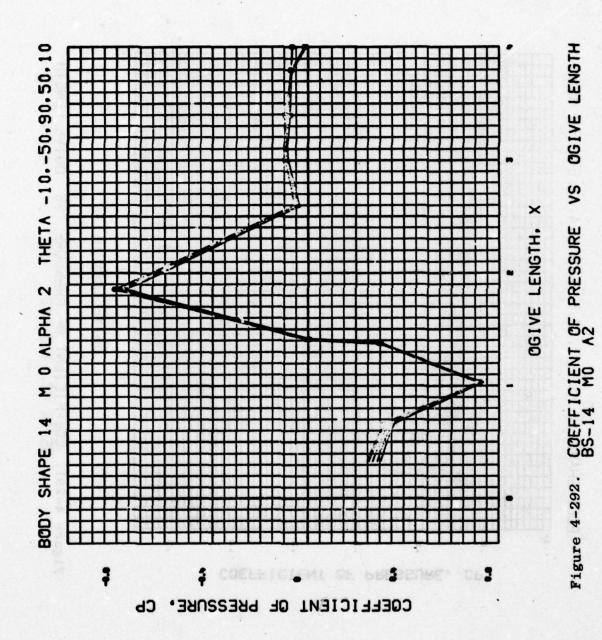
BODY SHAPE 14

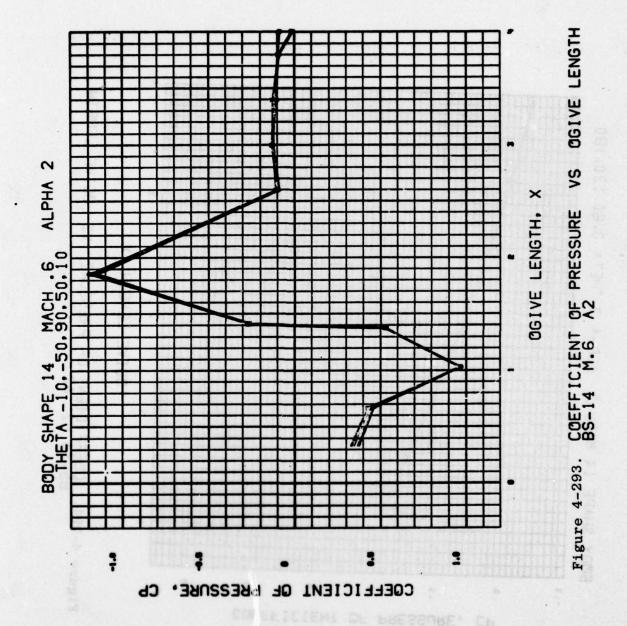


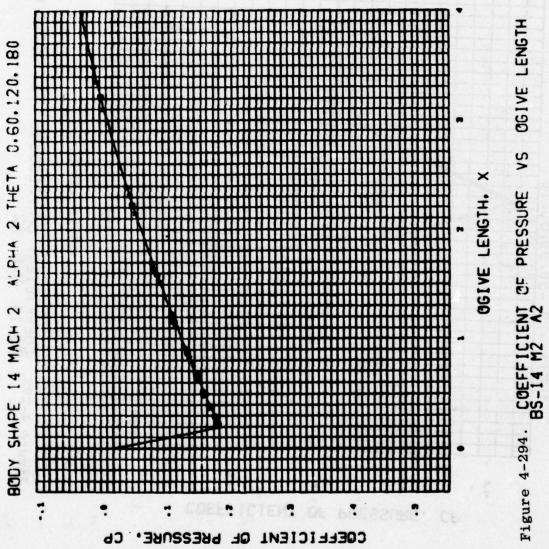












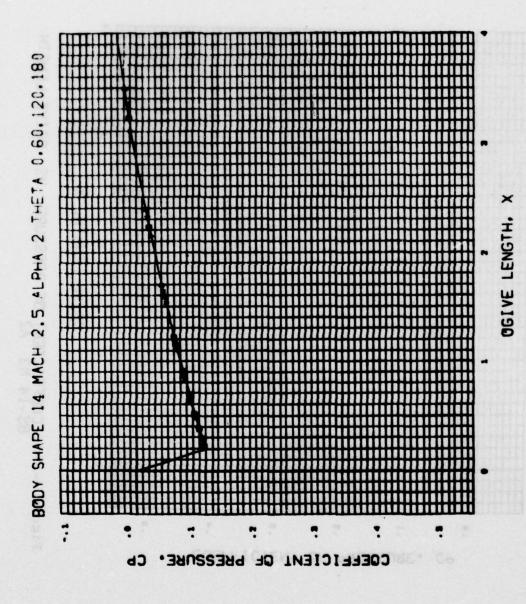


Figure 4-295. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-14 M2.5 A2

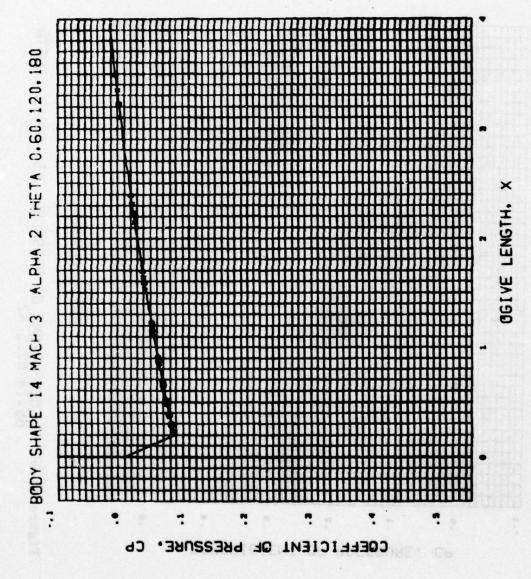
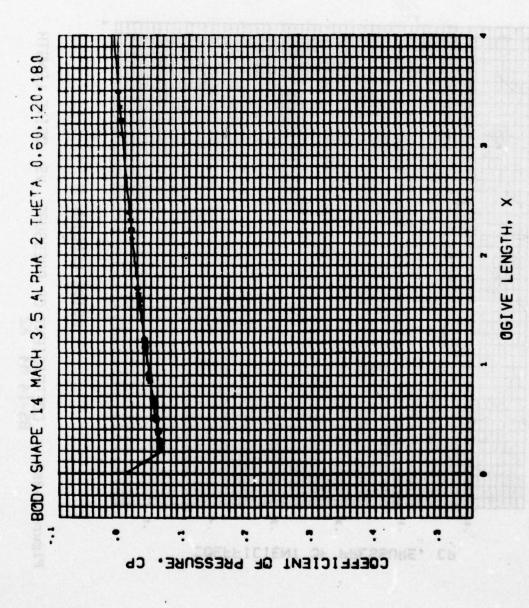
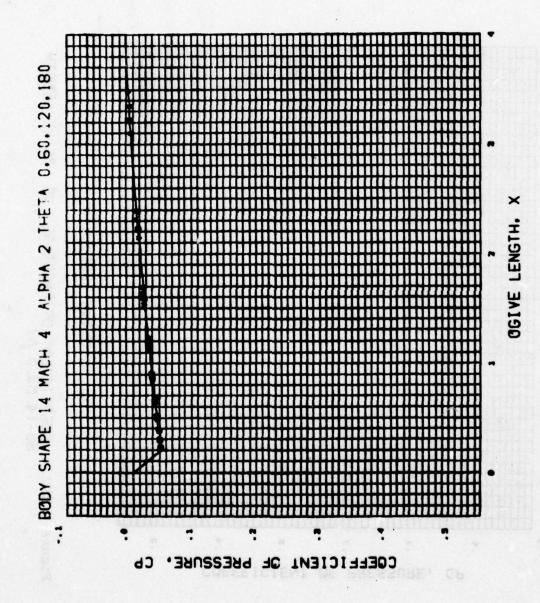


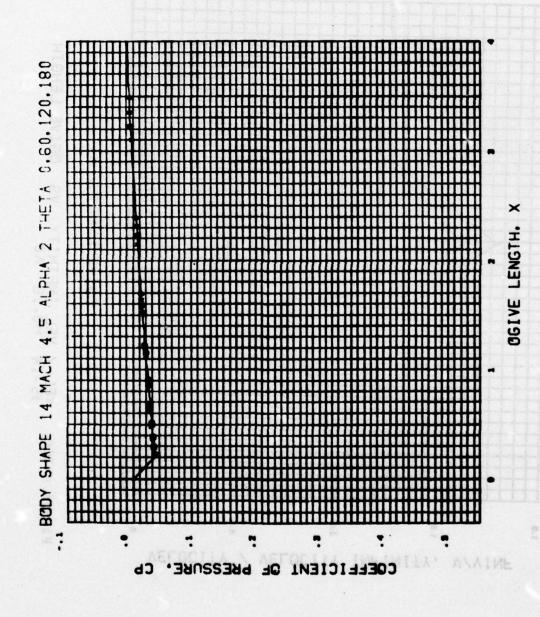
Figure 4-296. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-14 M3 A2



ure 4-297. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-14 M3.5 A2



OGIVE LENGTH ۸S COEFFICIENT OF PRESSURE BS-14 M4 A2 Figure 4-298.



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-14 M4.5 A2 Figure 4-299.

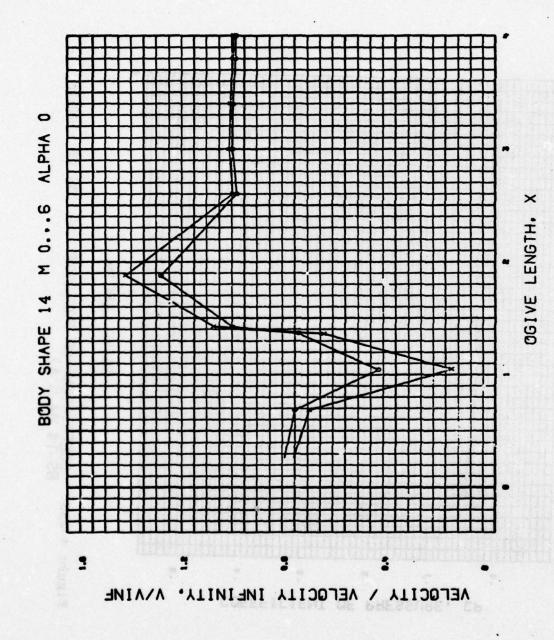


Figure 4-300. VEL / VEL INFINITY VS OGIVE LENGTH 35-14 M0.6 A0

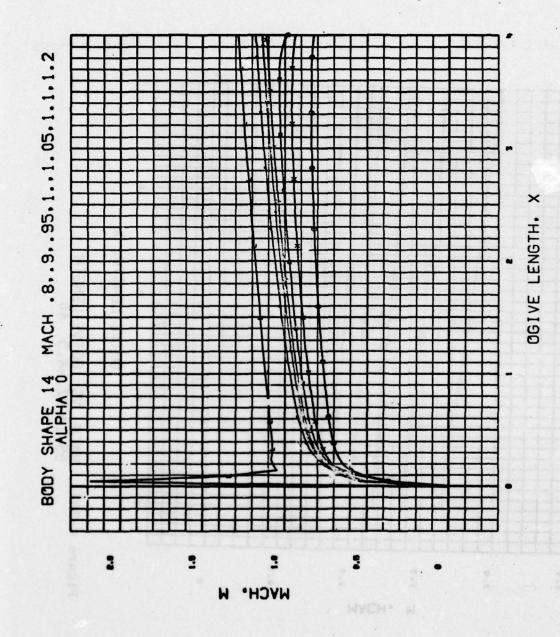
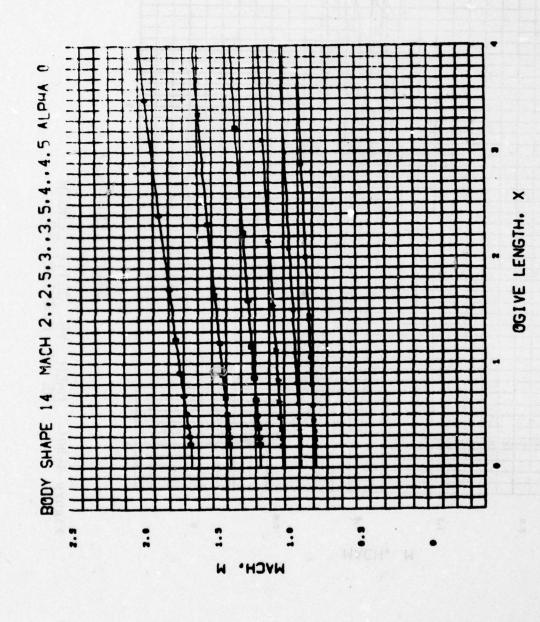


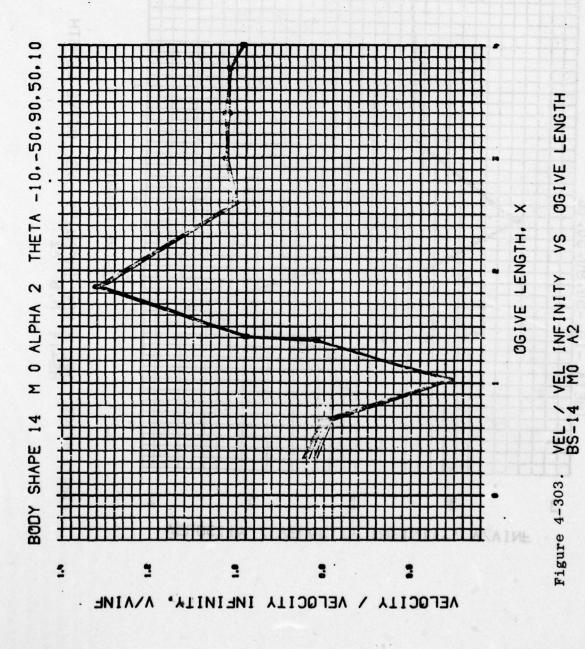
Figure 4-301. MACH VS 06IVE LENGTH BS-14 M.8-1.2 A0

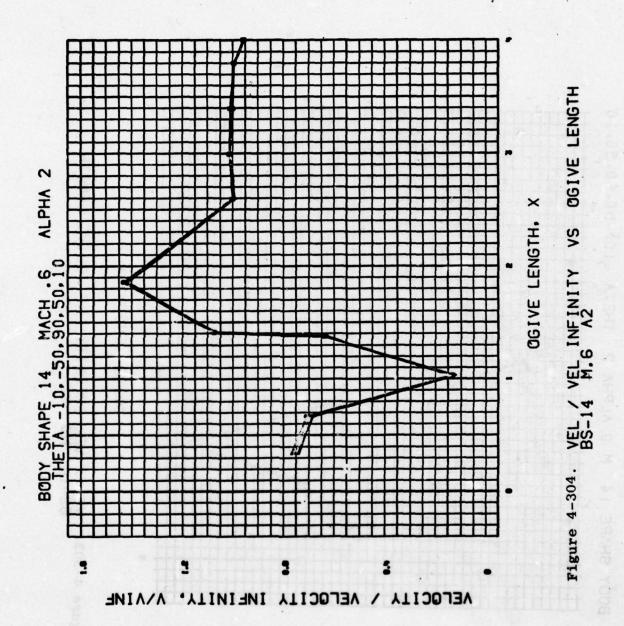


MACH VS OGIVE LENGTH BS-14 M2.-4.5 AD

Figure 4-302.

344





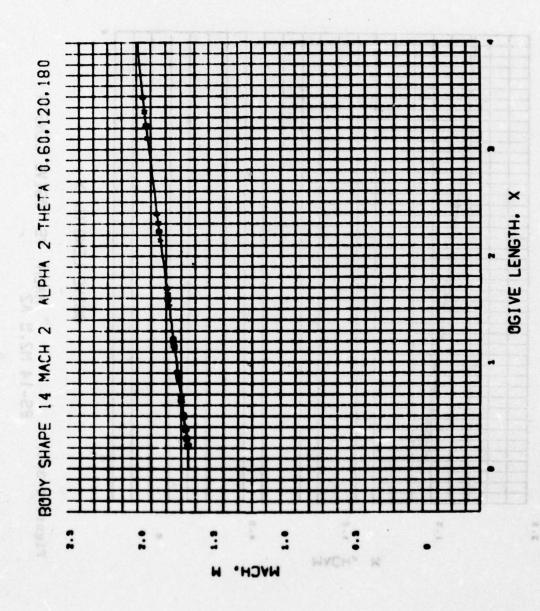


Figure 4-305. BS-14 M2 A2

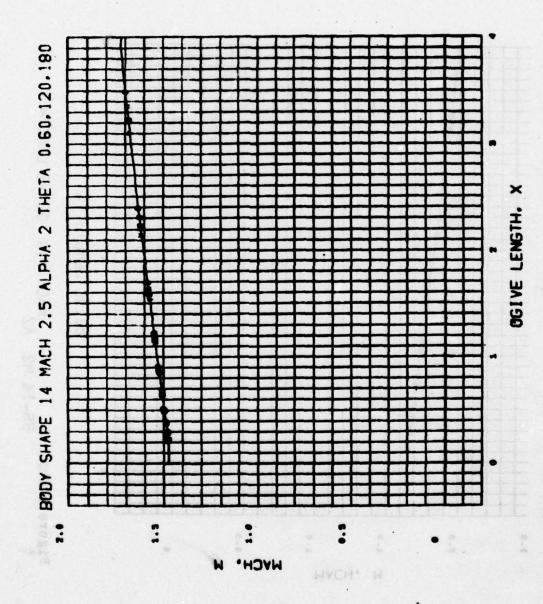


Figure 4-306. BS-14 M2.5 A2

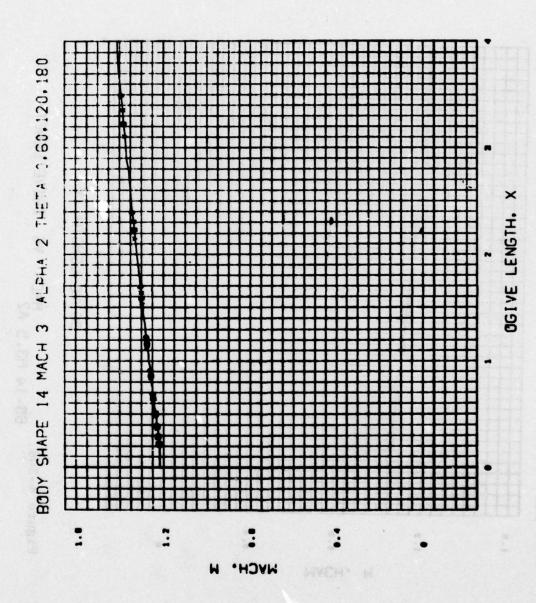


Figure 4-307. BS-14 M3 A2

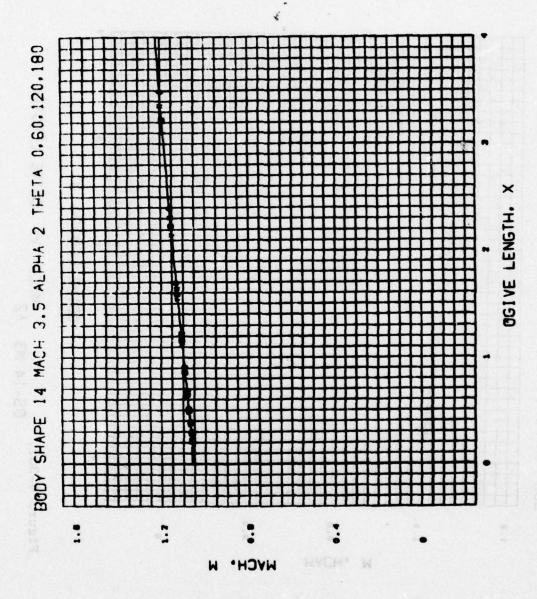


Figure 4-308. BS-14 M3.5 A2

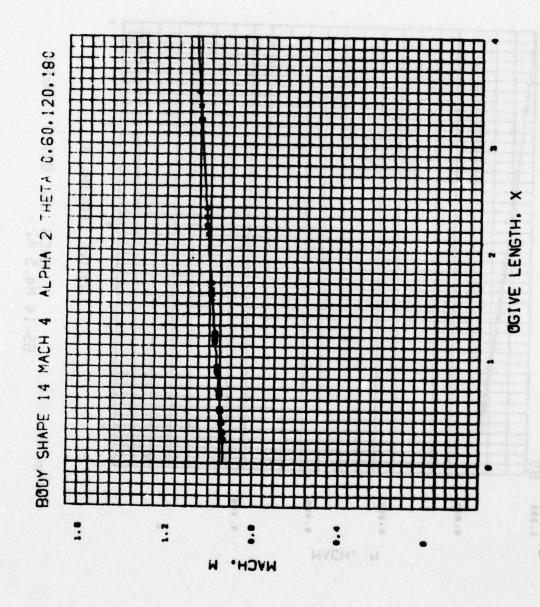
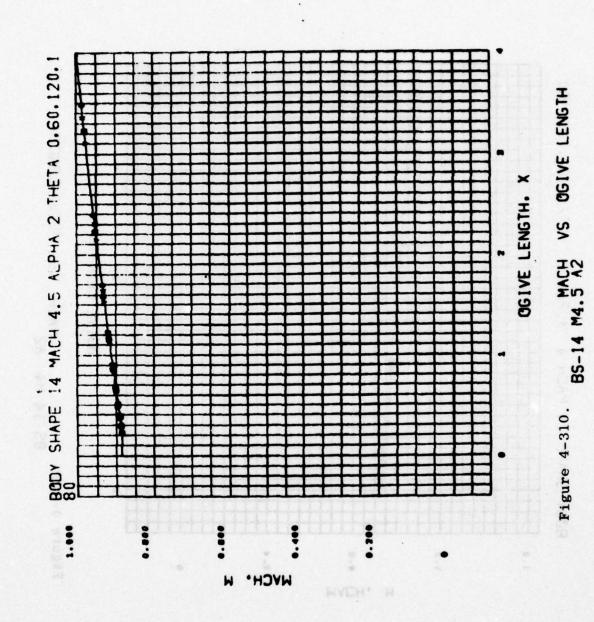


Figure 4-309. BS-14 M4 A2

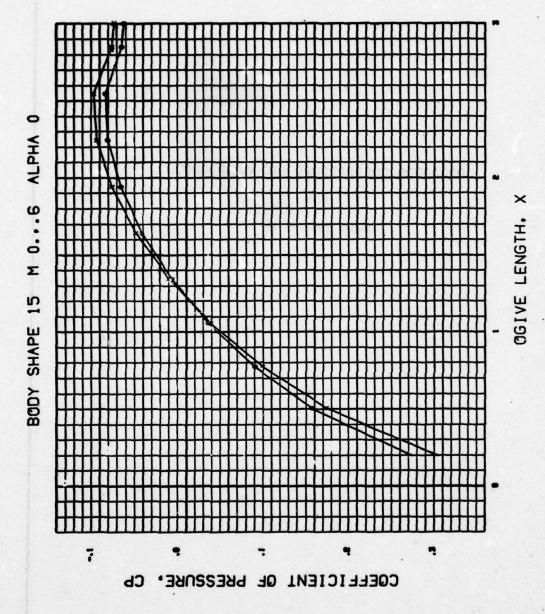


PRESSURE COEFFICIENT AND MACH PLOTS

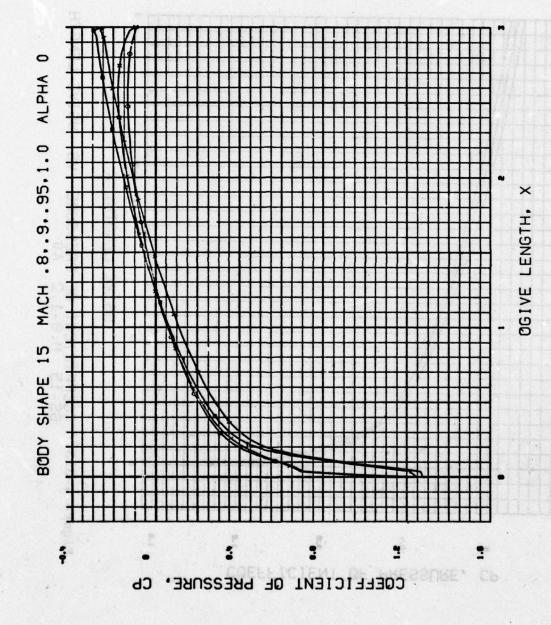
FOR

BODY SHAPE 15

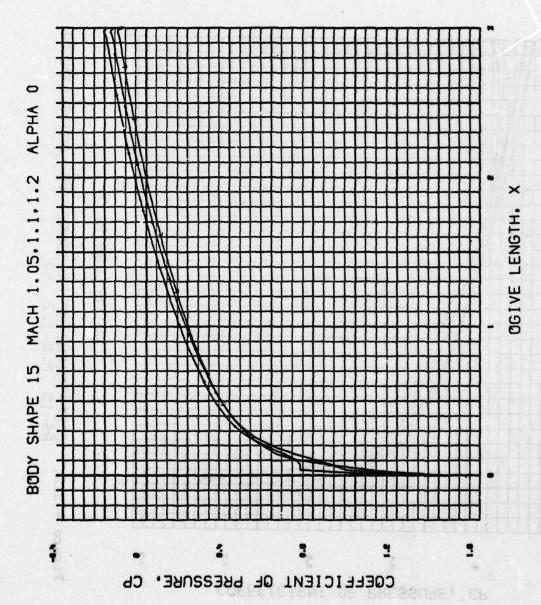
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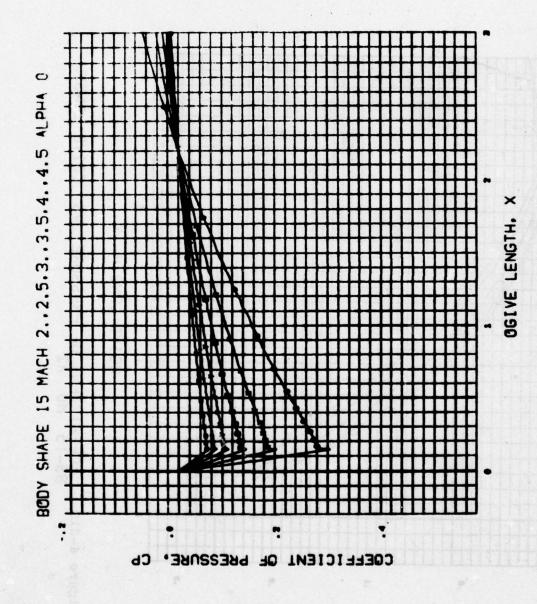
OGIVE LENGTH ۸S Figure 4-311. COEFFICIENT OF PRESSURE BS-15 M0..6 A0



OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-15 M.8-1.2 A0 Figure 4-312.



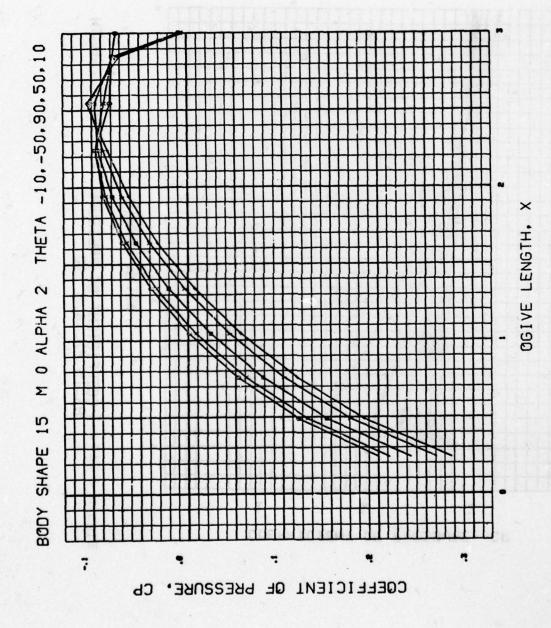
COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-15 M.8-1.2 A0 Figure 4-313.



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-15 M2. -4.5 A0

Figure 4-314.

357



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-15 M0 A2 Figure 4-315.

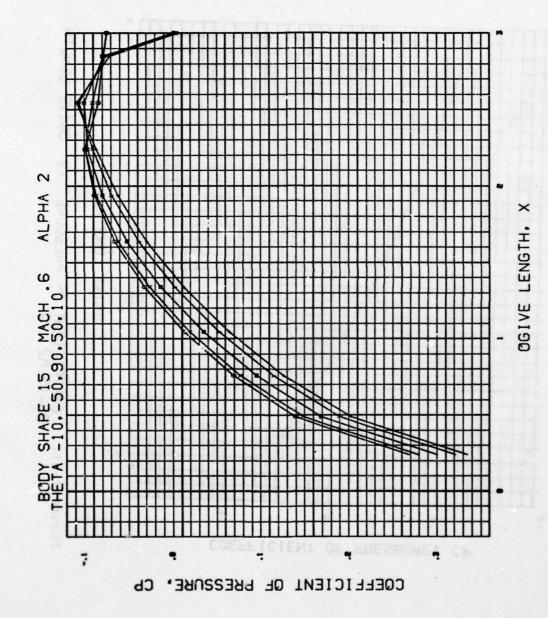


Figure 4-316. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-15 M.6 A2

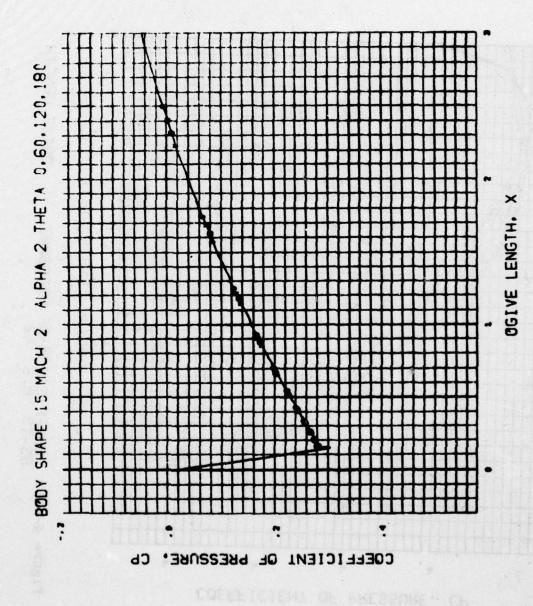


Figure 4-317. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-15 M2 A2

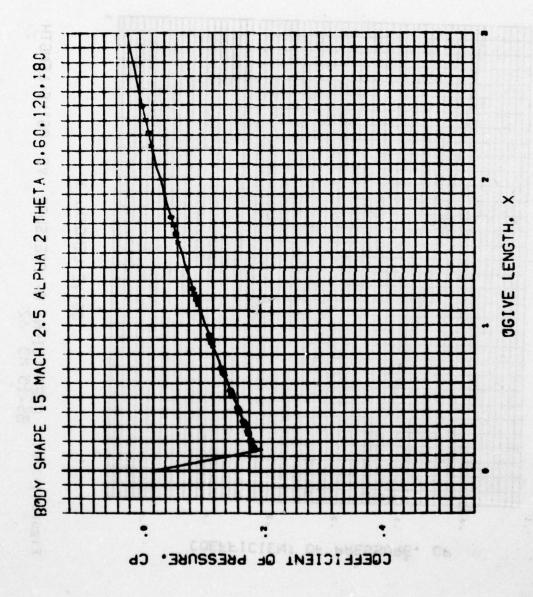
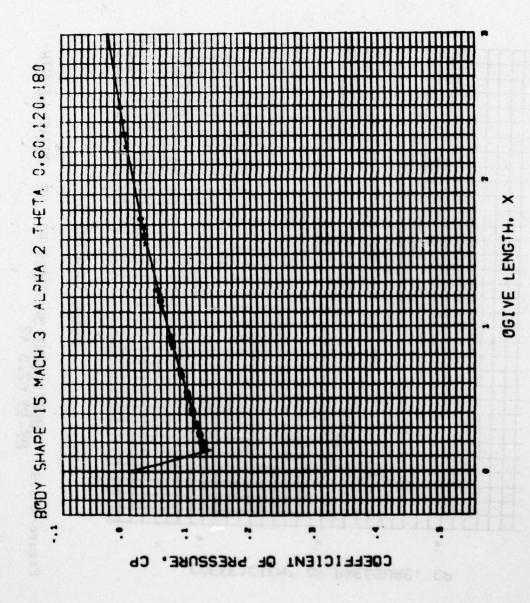
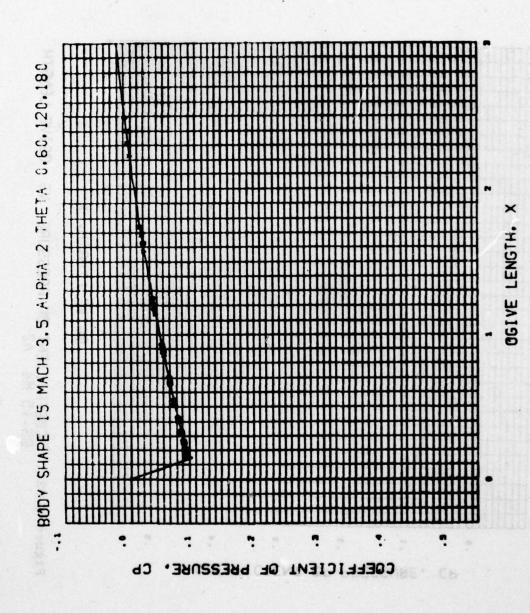


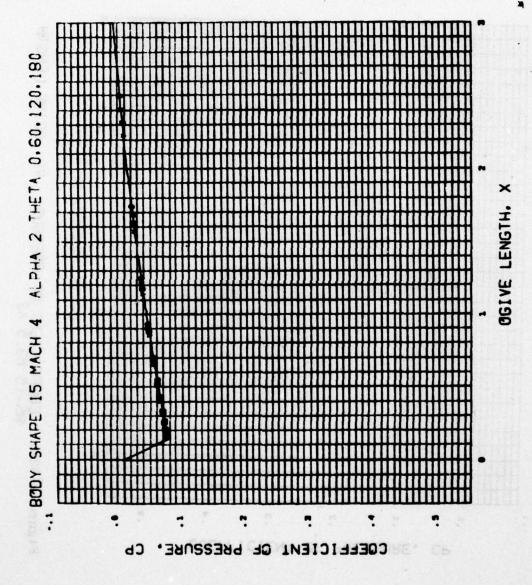
Figure 4-318. COEFFICIENT OF PRESSURE VS OGIVE LENGTH



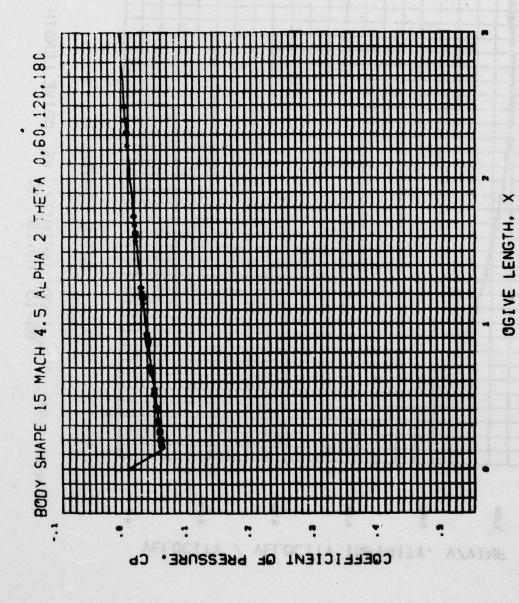
OGIVE LENGTH ٧S COEFFICIENT OF PRESSURE BS-15 M3 A2 Figure 4-319.



OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-15 M3.5 A2 Figure 4-320.



OGIVE LENGTH ٧S COEFFICIENT OF PRESSURE BS-15 M4 A2 Figure 4-321.



ure 4-322. COEFFICIENT OF PRESSURE VS OGIVE LENGTH

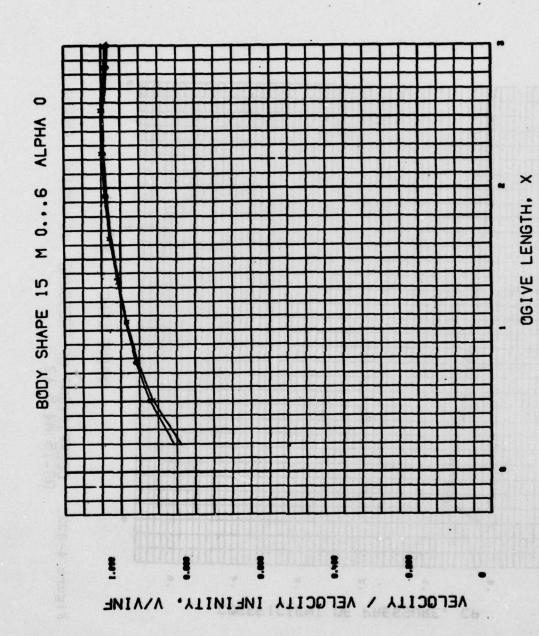


Figure 4-323. VEL / VEL INFINITY VS OGIVE LENGTH

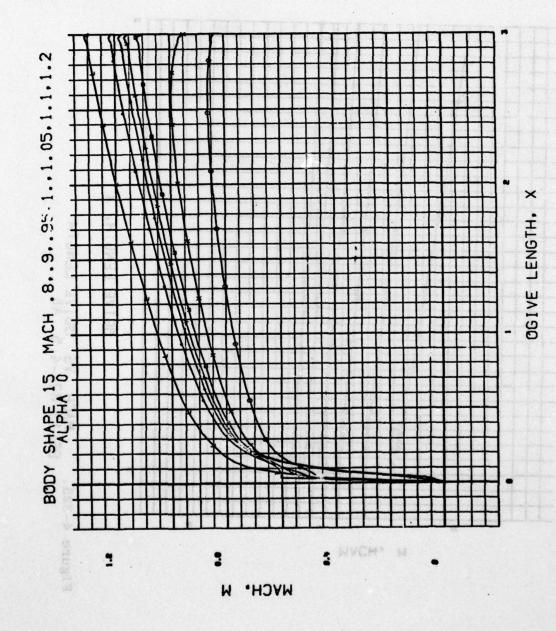


Figure 4-324. MACH VS 0GIVE LENGTH BS-15 M.8-1.2 A0

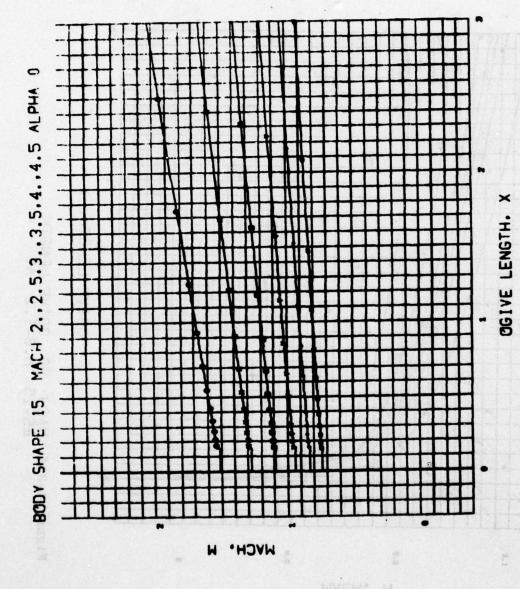


Figure 4-325. MACH VS OGIVE LENGTH BS-15 M2.-4.5 A0

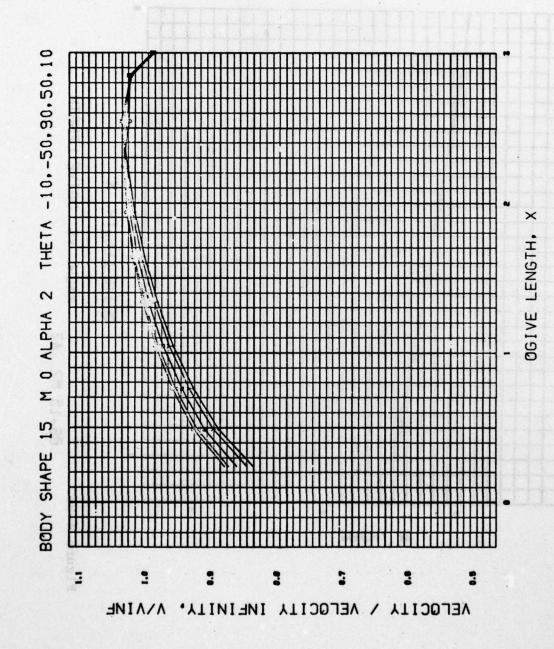


Figure 4-326. VEL / VEL INFINITY VS OGIVE LENGTH BS-15 M0 A2

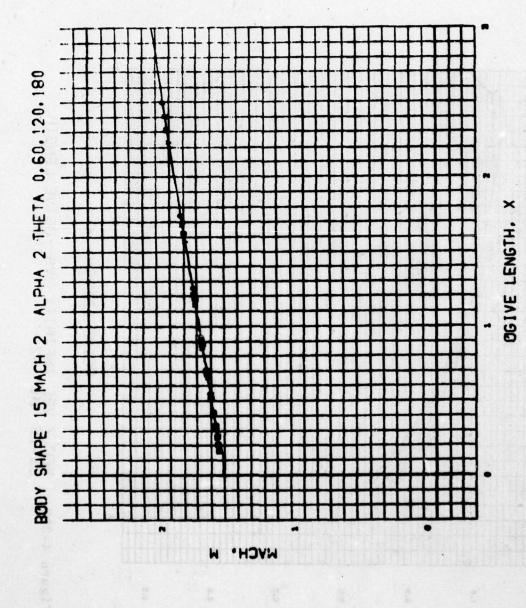


Figure 4-327. BS-15 M2 A2 MACH VS

MACH VS OGIVE LENGTH

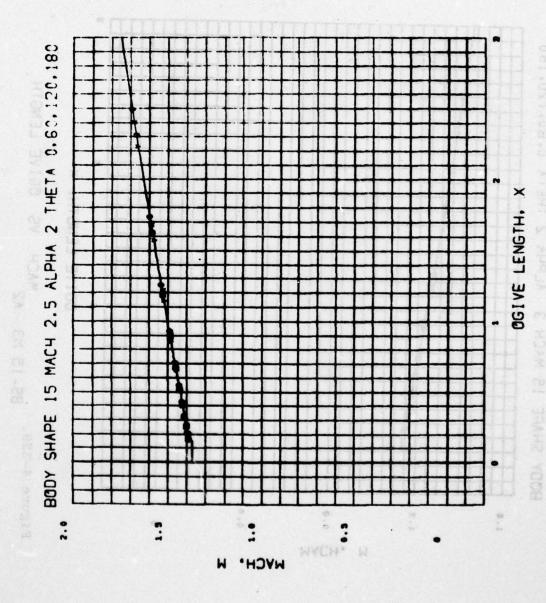


Figure 4-328. BS-15 M2.5 A2

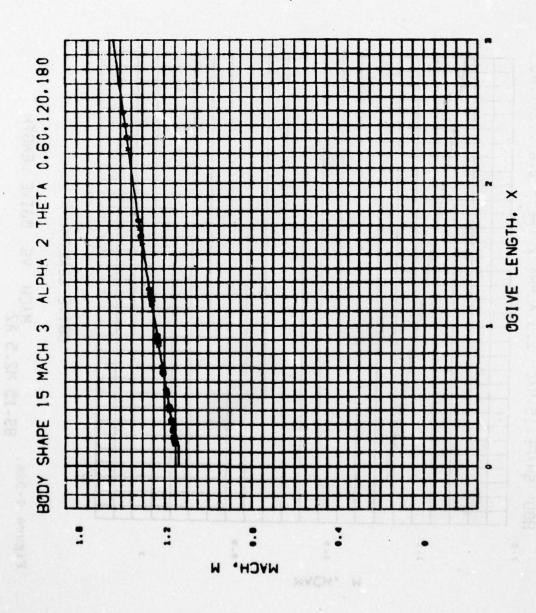
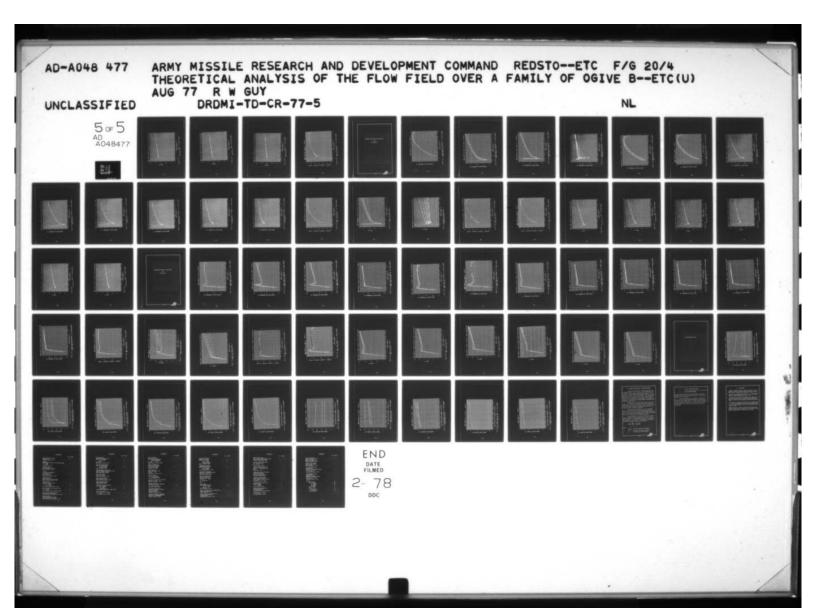
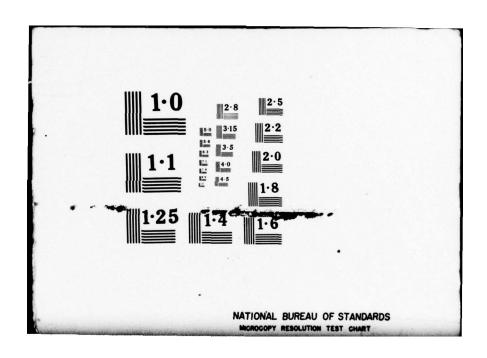


Figure 4-329. BS-15 M3 A2 MACH VS @GIVE LENGTH





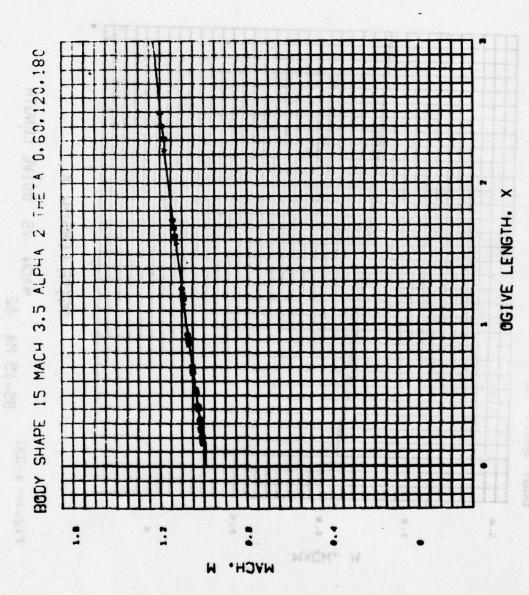


Figure 4-330. 85-15 M3.5 A2

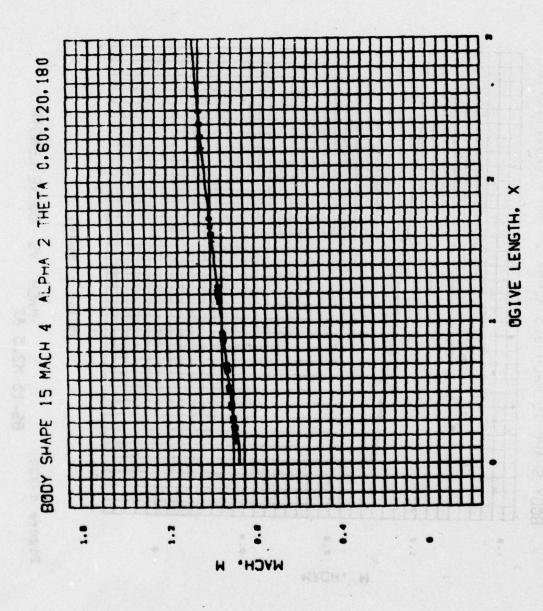


Figure 4-331. 85-15 M4 A2

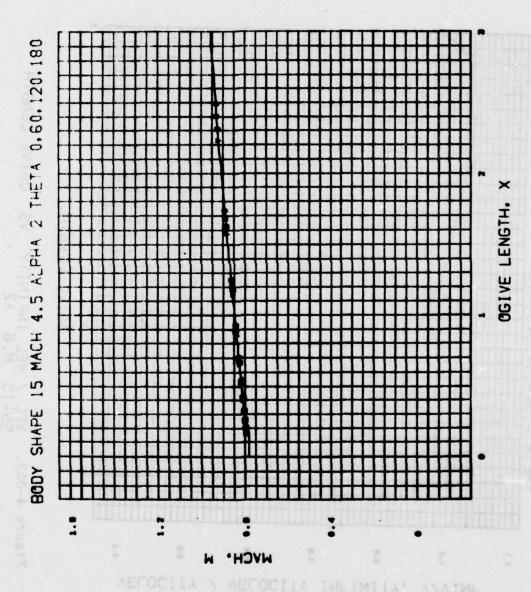
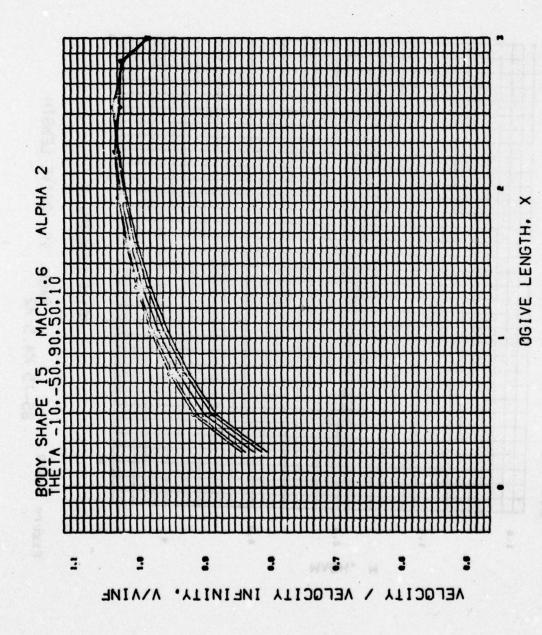


Figure 4-332. BS-15 M4.5 A2



OGIVE LENGTH VEL / VEL INFINITY VS BS-15 M.6 A2

PRESSURE COEFFICIENT AND MACH PLOTS

FOR

BODY SHAPE 16

COEFFICIENT OF PRESCURE, CP.

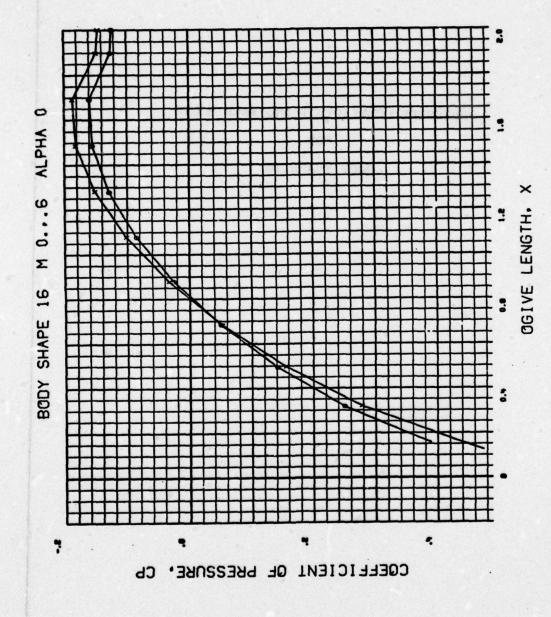
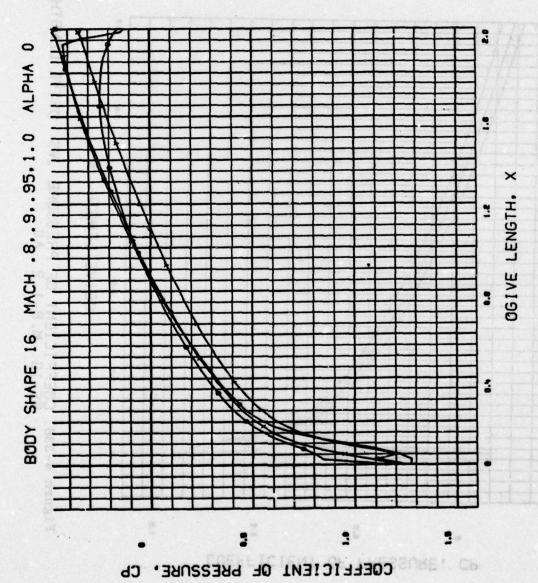
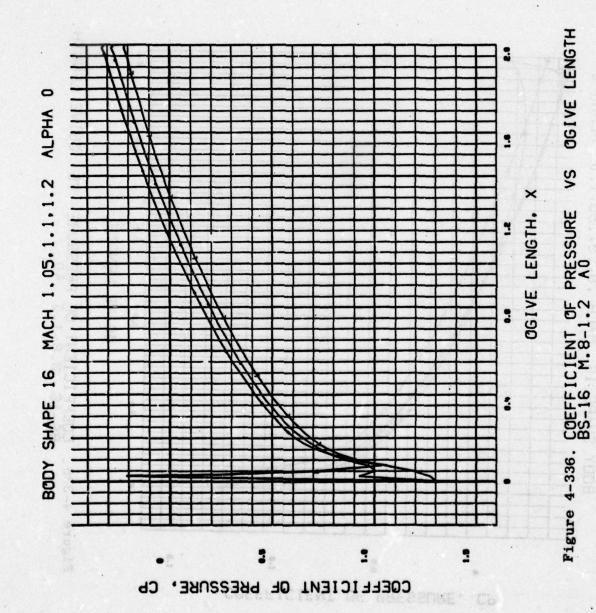
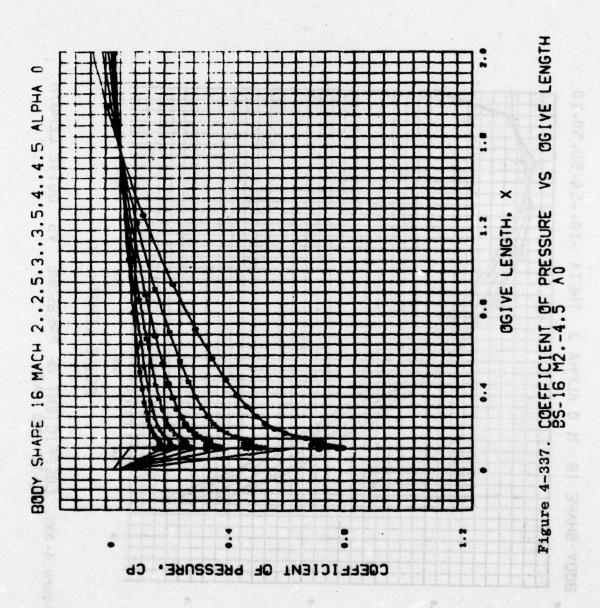


Figure 4-334. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-16 MO..6 A0



OGIVE LENGTH COEFFICIENT OF PRESSURE VS BS-16 M.8-1.2 A0 Figure 4-335.





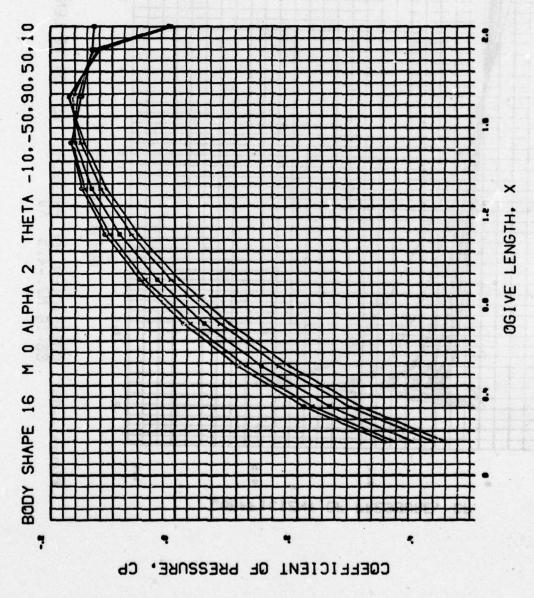
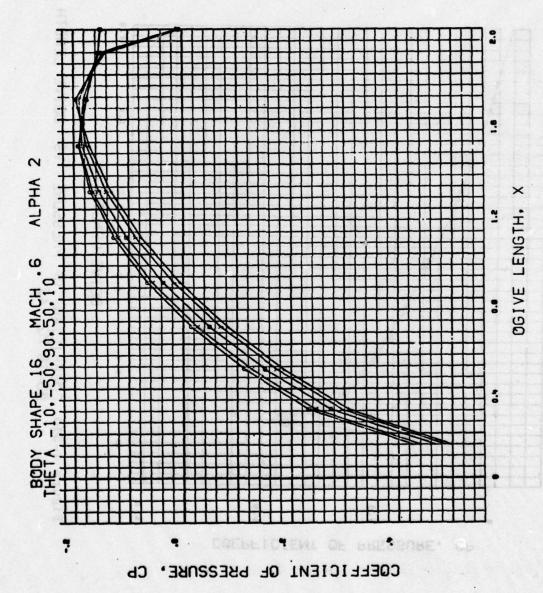
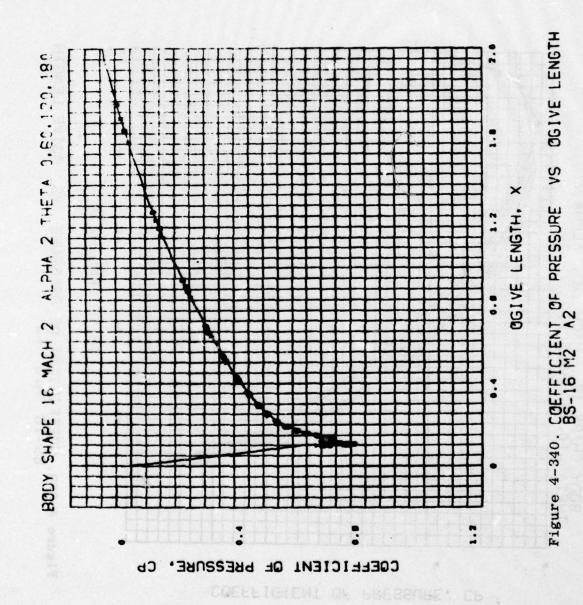


Figure 4-338. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-16 M0 A2



OGIVE LENGTH ۸S Figure 4-339, COEFFICIENT OF PRESSURE BS-16 M.6 A2



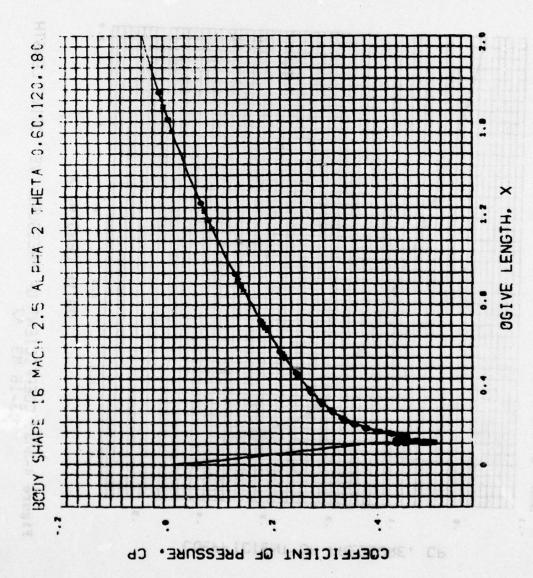


Figure 4-341. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS.15 M2.5 A2

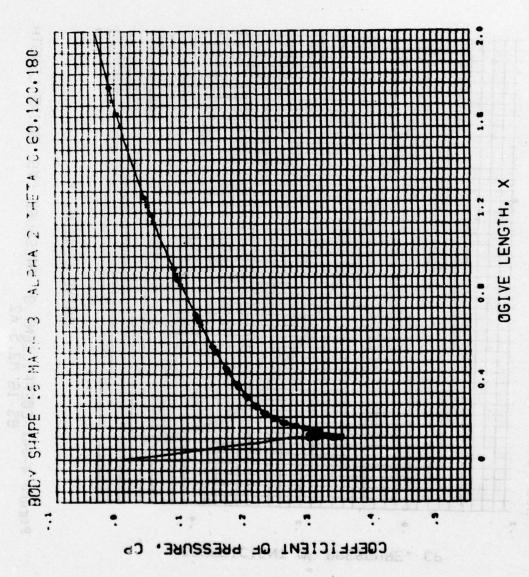
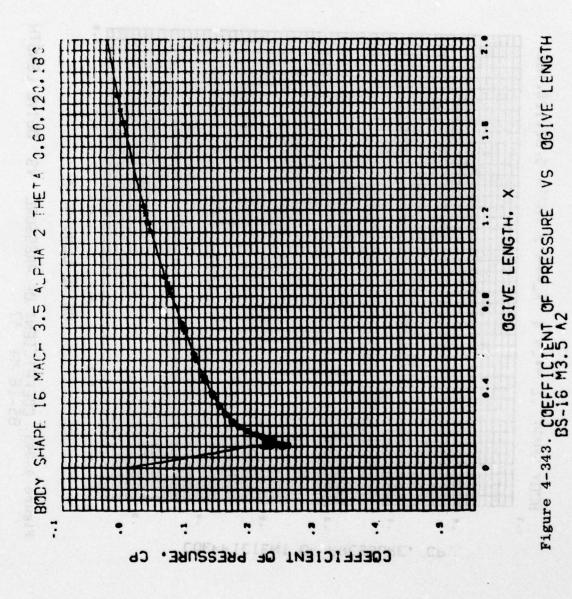


Figure 4-342, COEFFICIENT OF PRESSURE VS OSIVE LENGTH BS-16 M3 A2



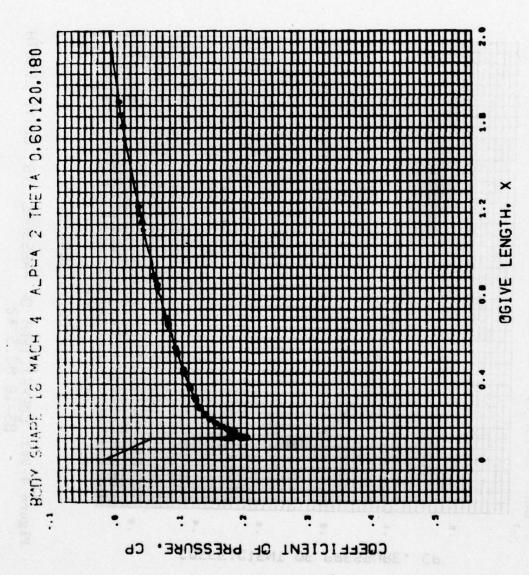


Figure 4-344. COEFFICIENT OF PRESSURE vS OGIVE LENGTH BS-16 M4 A2

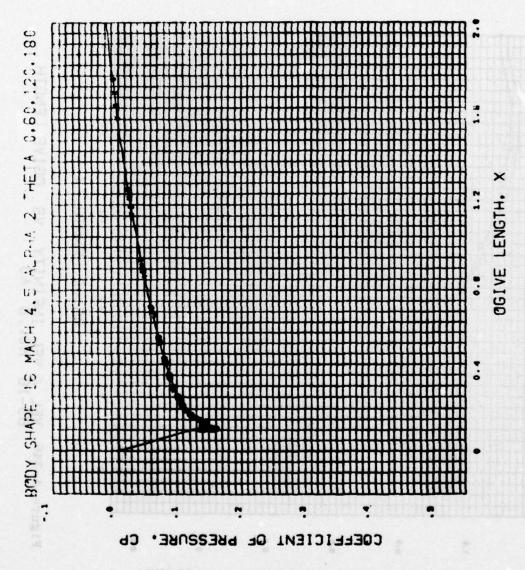


Figure 4-345. COEFFICIENT OF PRESSURE VS OGIVE LENGTH 95-16 M4.5 A2

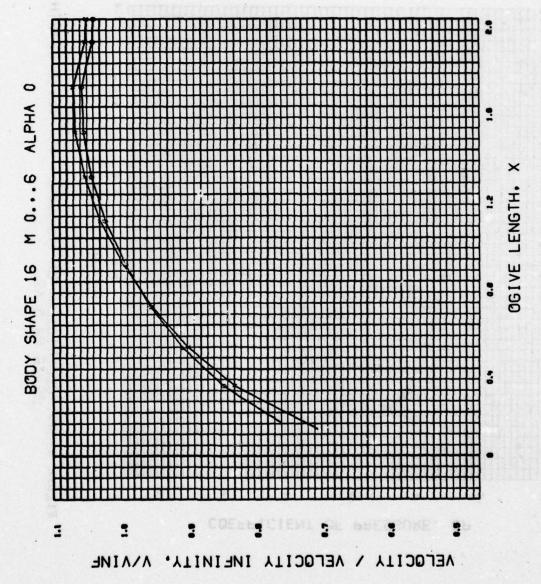


Figure 4-346. VEL / VEL INFINITY VS OGIVE LENGTH BS-16 MO.6 A0

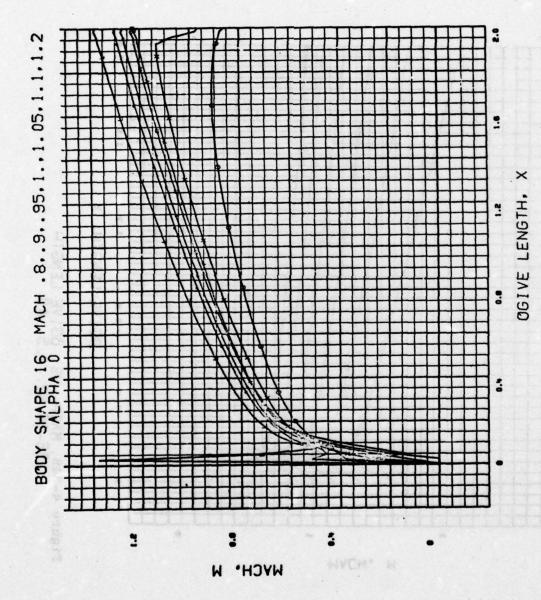


Figure 4-347. MACH VS 061VE LENGTH BS-16 M.8-1.2 A0

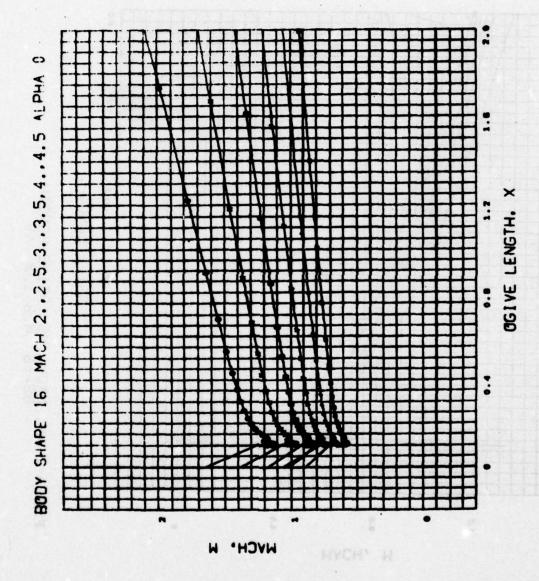
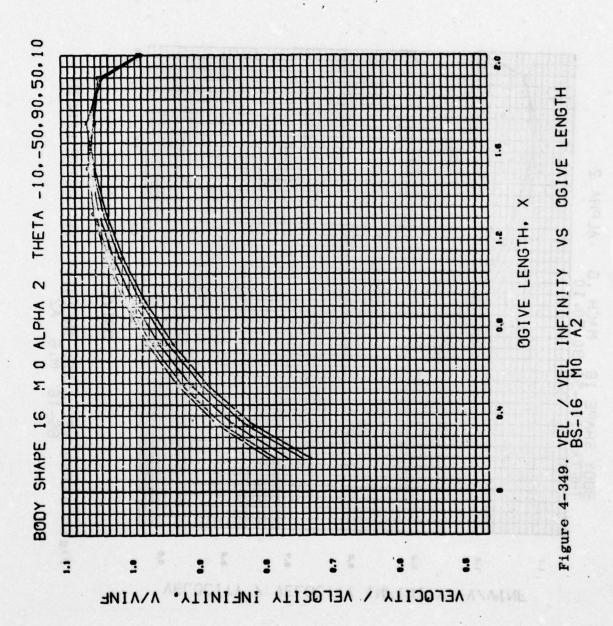
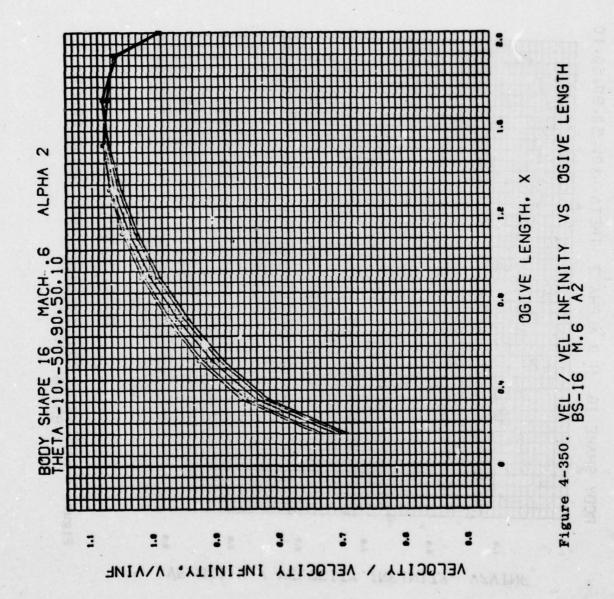


Figure 4-348. MACH VS 0GIVE LENGTH BS-16 M2.-4.5 A0





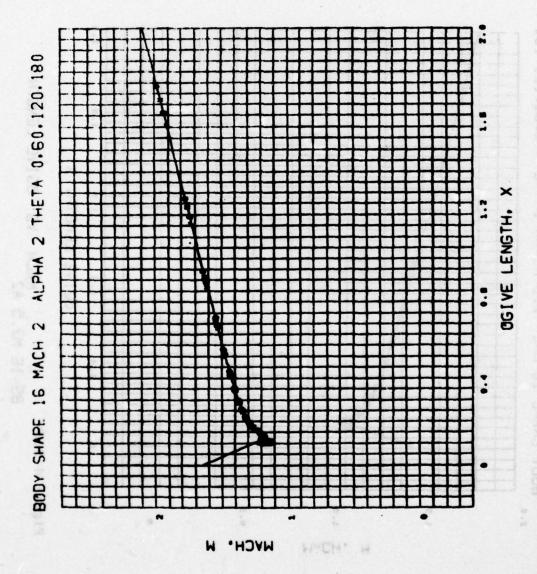


Figure 4-351. BS-15 MZ AZ MACH VS @GIVE LENGTH

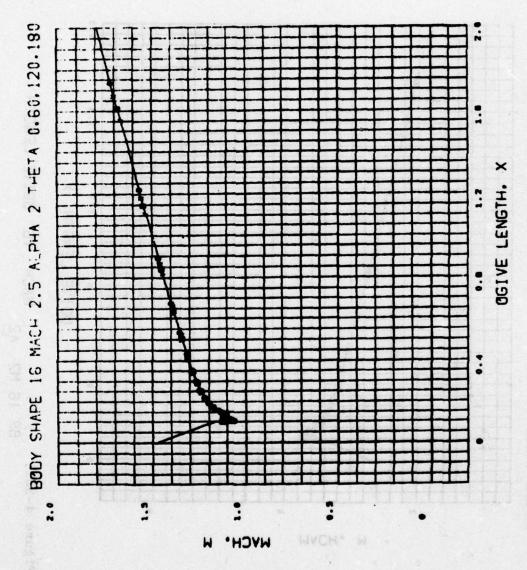
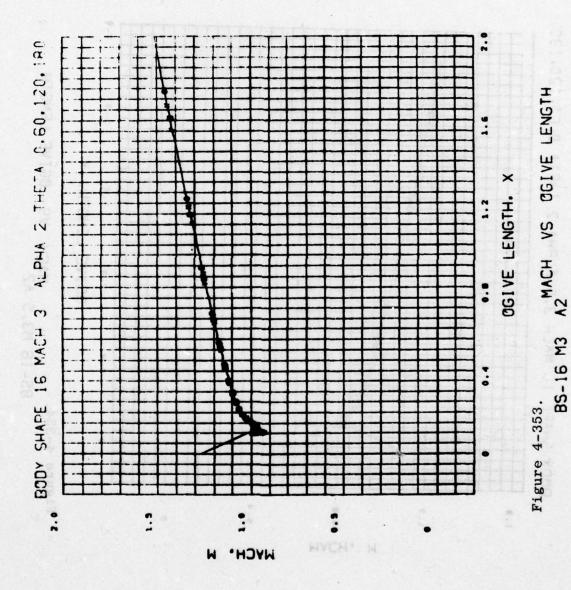
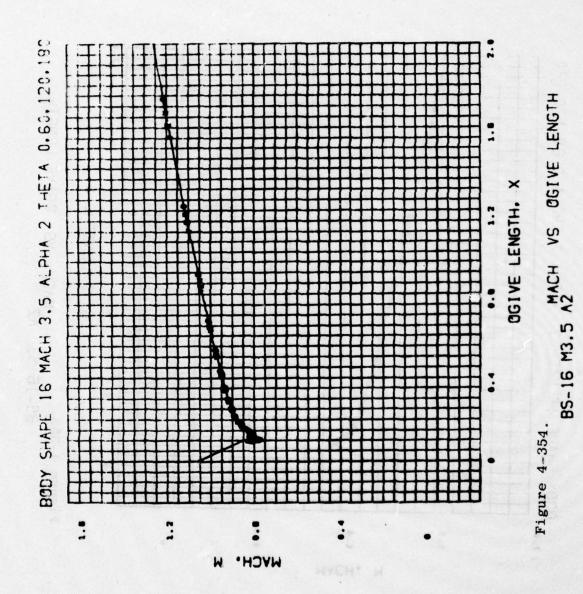


Figure 4-352.

BS-16 M2.5 A2





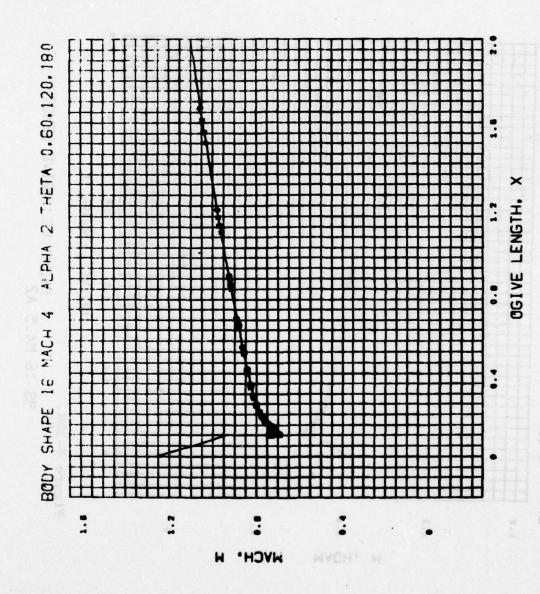
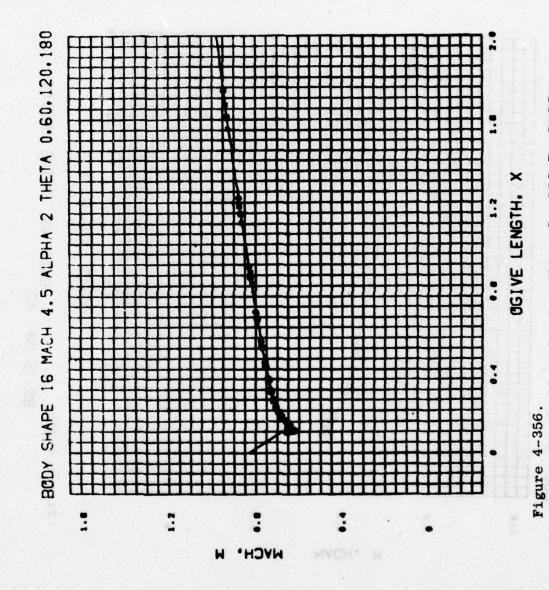


Figure 4-355.

MACH VS @GIVE LENGTH
BS-16 M4 A2



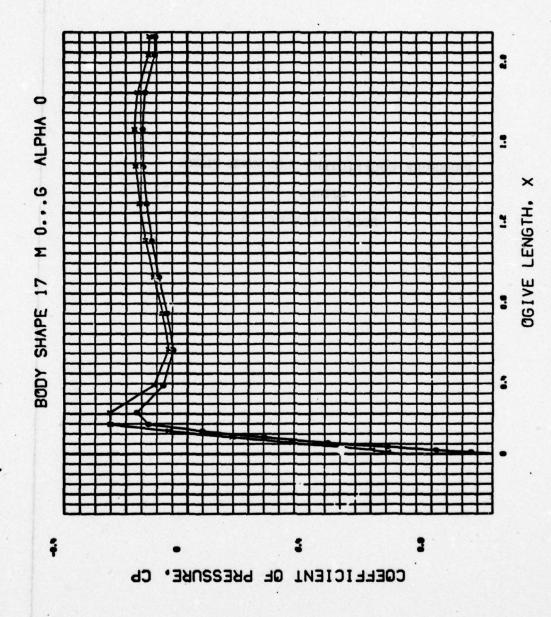
BS-16 M4.5 A2

PRESSURE COEFFICIENT AND MACH PLOTS

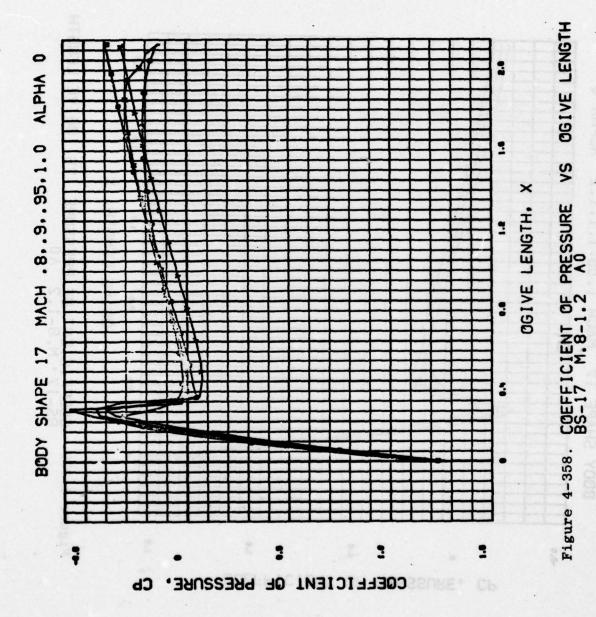
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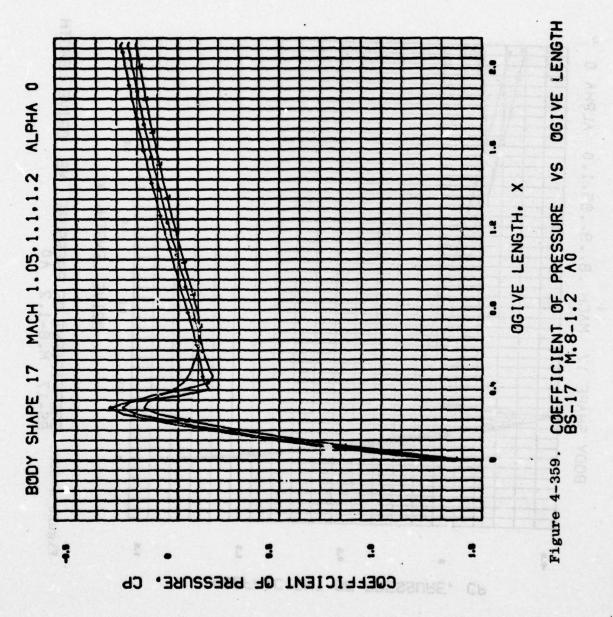
BODY SHAPE 17

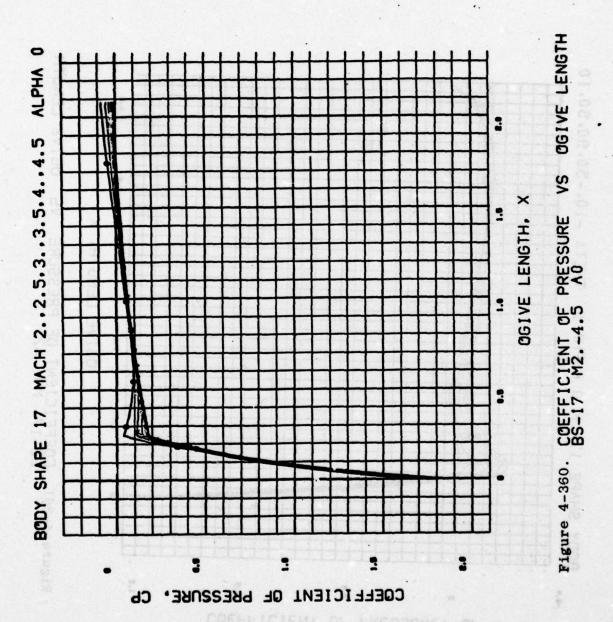
CREFFICIENT OF PRESSURE. CP



COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-17 MO..6 A0 Figure 4-357.







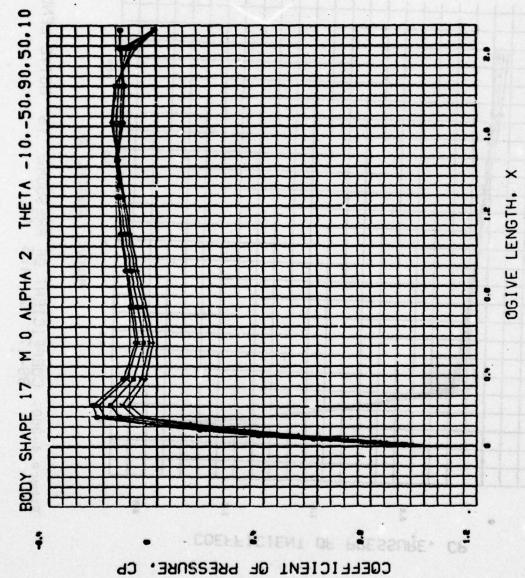
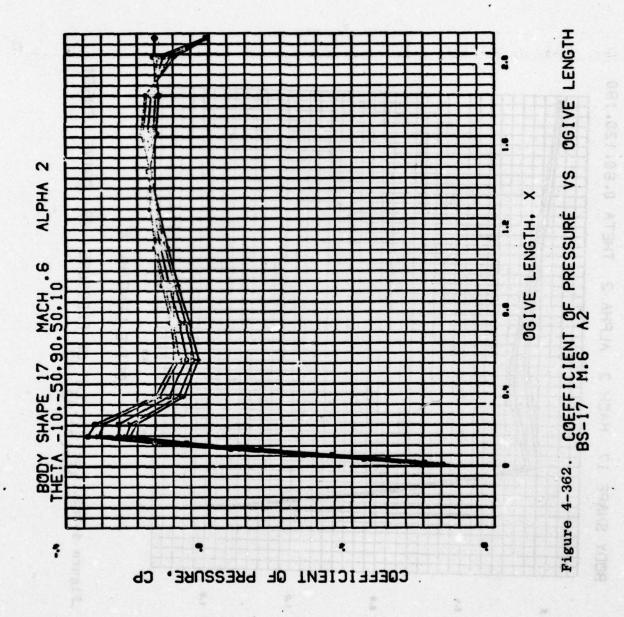


Figure 4-361. COEFFICIENT OF PRESSURE VS OGIVE LENGTH
BS-17 M0 A2



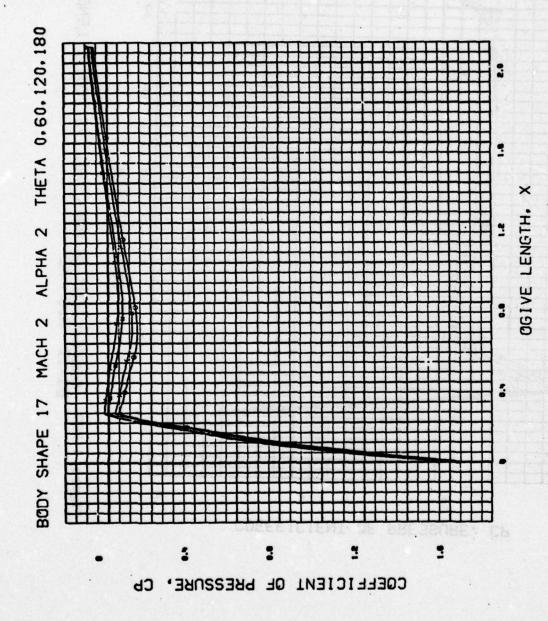
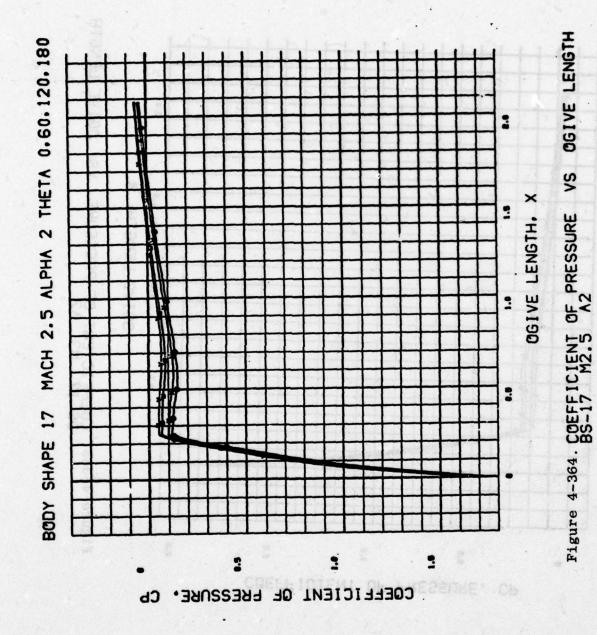
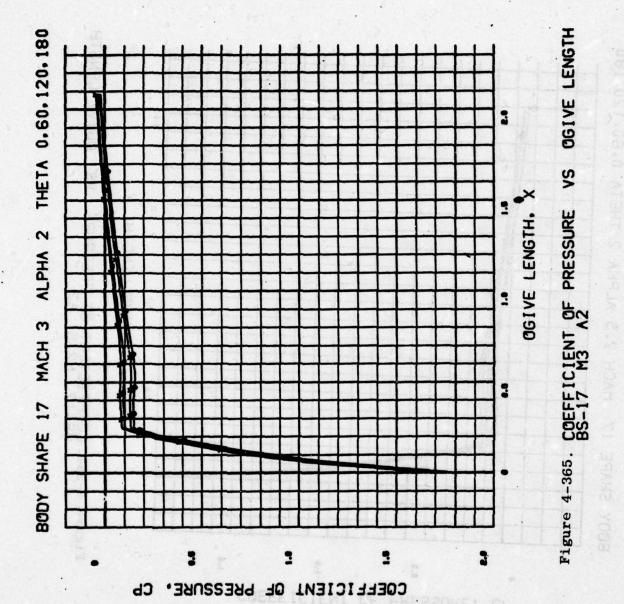
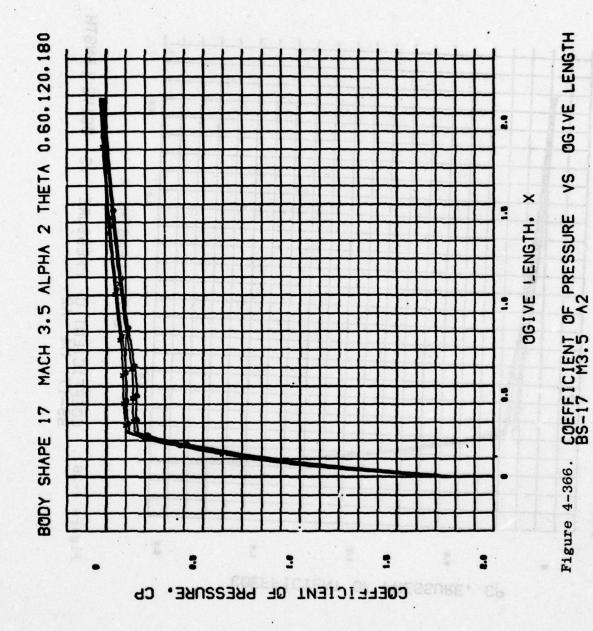
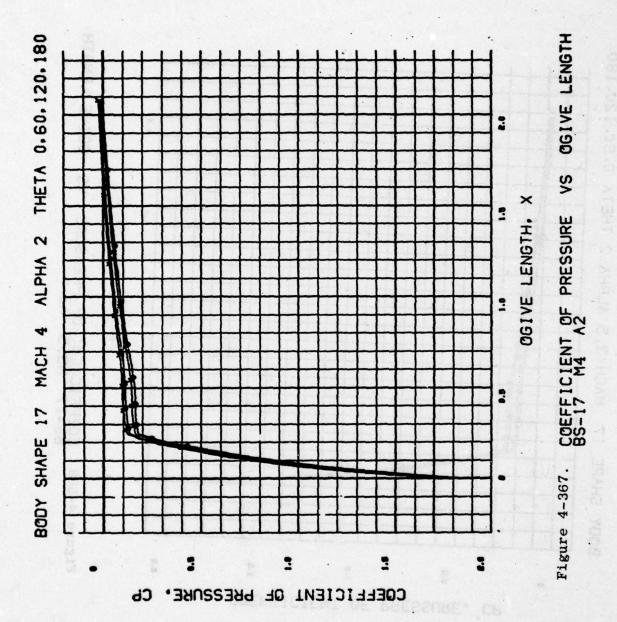


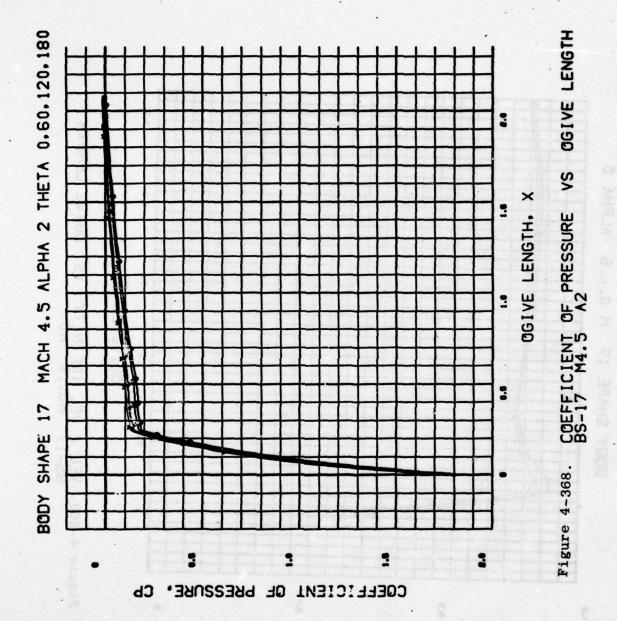
Figure 4-363. COEFFICIENT OF PRESSURE VS OGIVE LENGTH BS-17 M2 A2

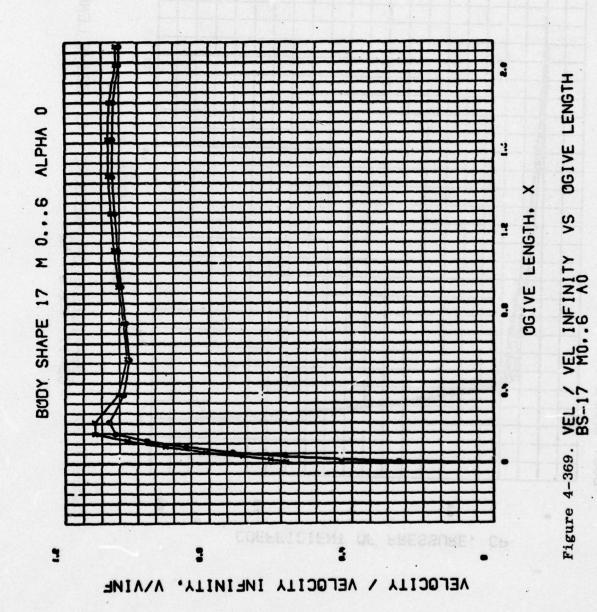


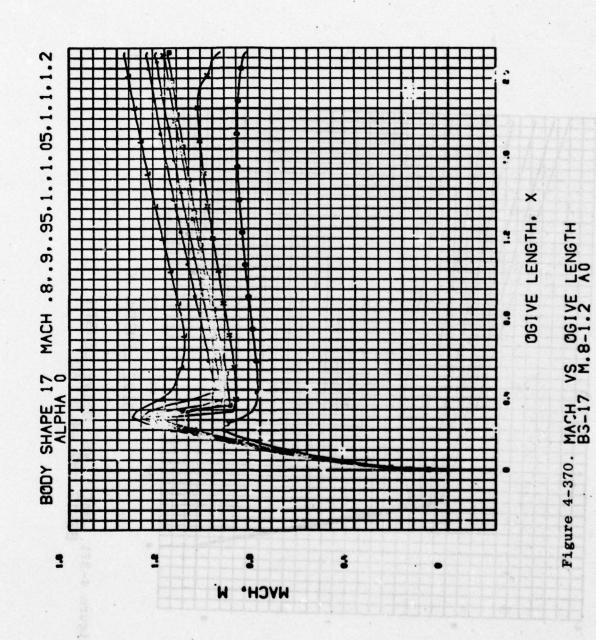












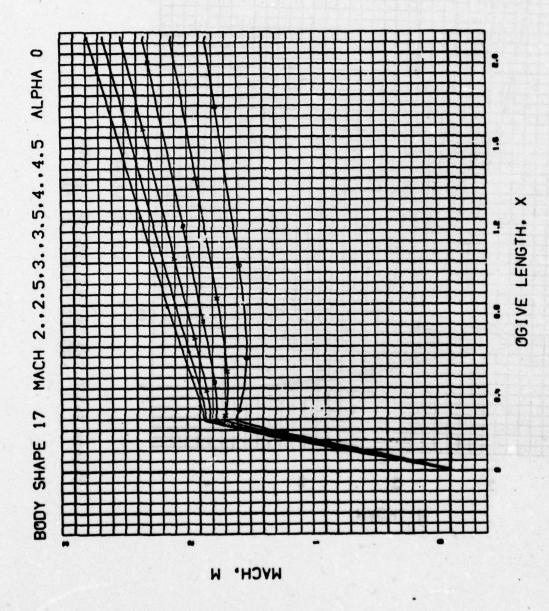


Figure 4-371, MACH VS 0GIVE LENGTH BS-17 M2.-4.5 A0

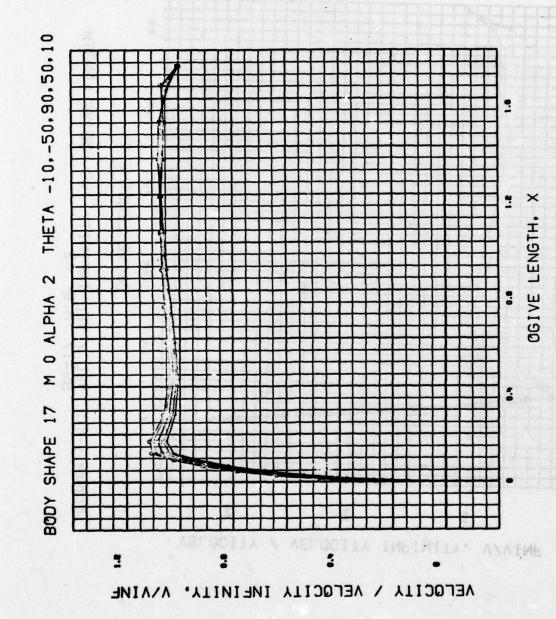
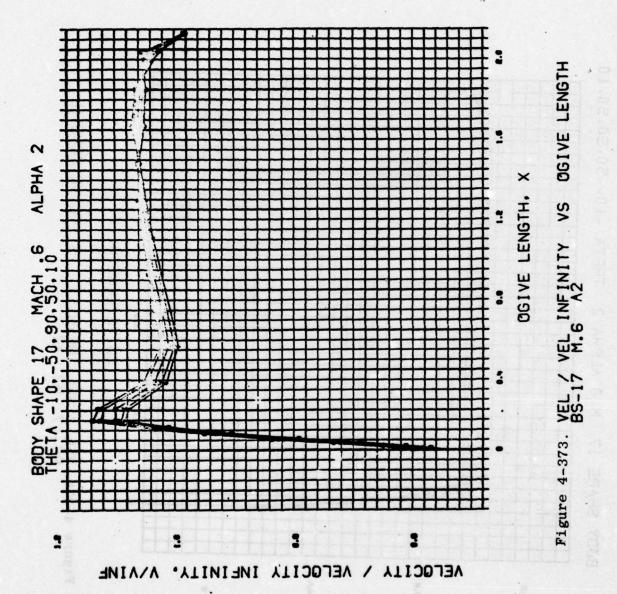


Figure 4-372. VEL / VEL INFINITY VS OGIVE LENGTH BS-17 MO A2



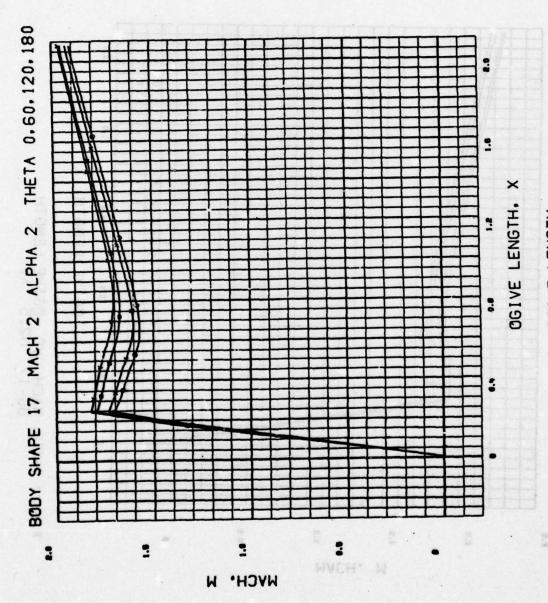


Figure 4-374. MACH VS OGIVE LENGTH BS-17 M2 A2

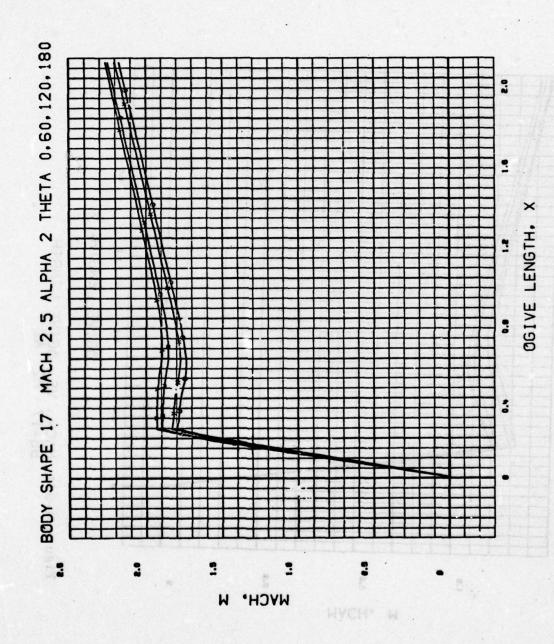


Figure 4-375. MACH VS 0GIVE LENGTH BS-17 M2.5 A2

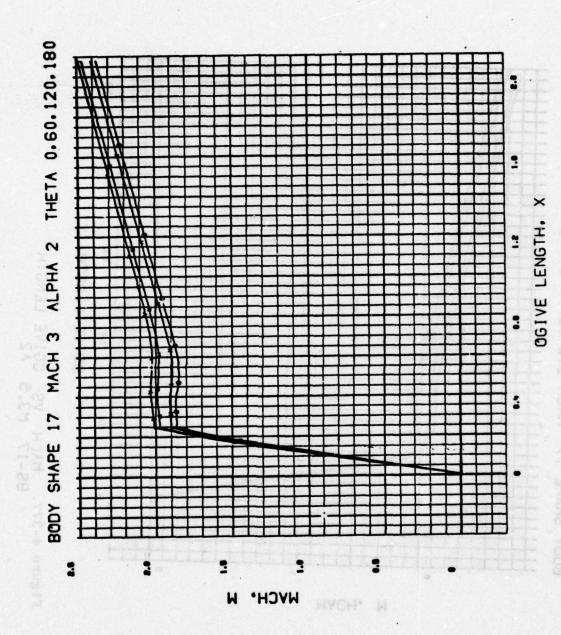


Figure 4-376. MACH VS OGIVE LENGTH BS-17 M3 A2

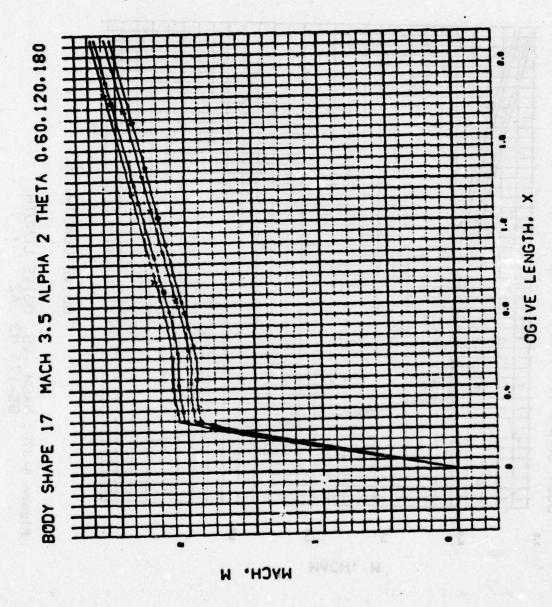


Figure 4-377. MACH VS OGIVE LENGTH BS-17 M3.5 A2

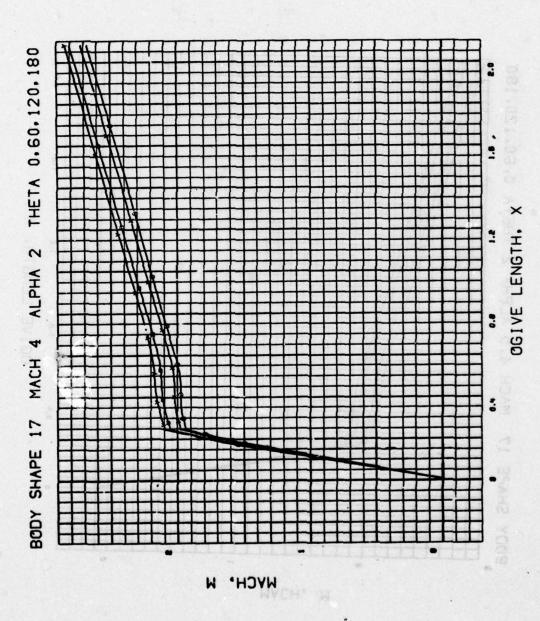


Figure 4-378. MACH VS OGIVE LENGTH BS-17 M4 A2

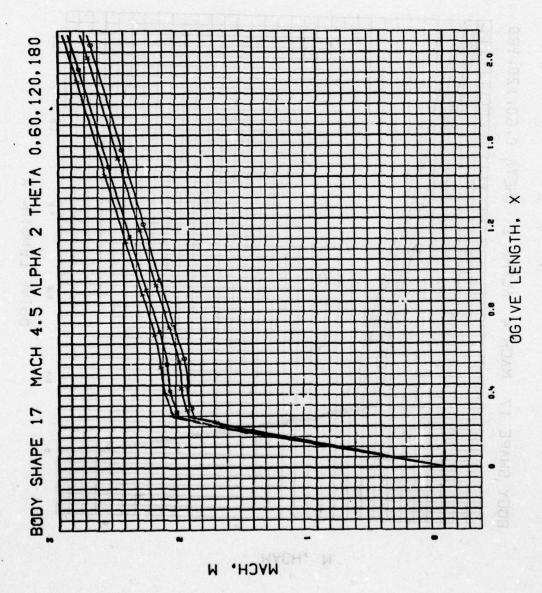


Figure 4-379. MACH VS OGIVE LENGTH BS-17 M4.5 A2

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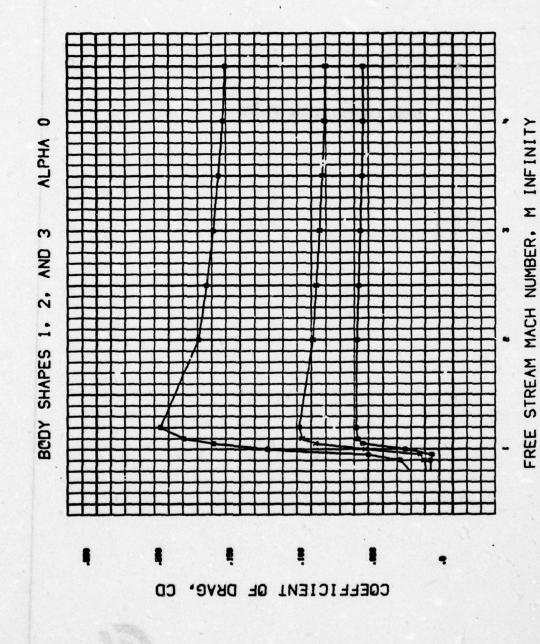
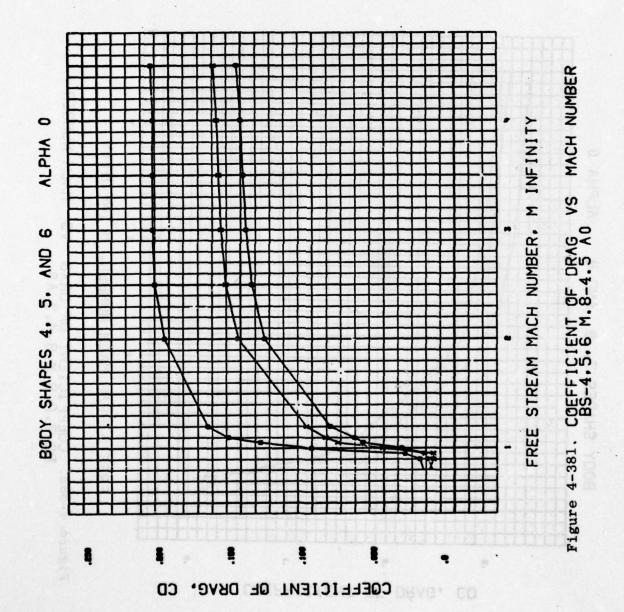


Figure 4-380. COEFFICIENT OF DRAG VS MACH NUMBER BS-1.2.3 M.8-4.5 A0



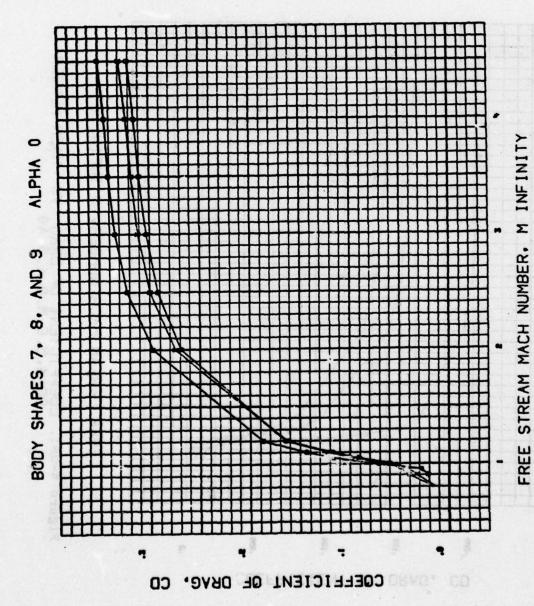


Figure 4-382. COEFFICIENT OF DRAG VS MACH NUMBER BS-7.8.9 M.8-4.5 A0

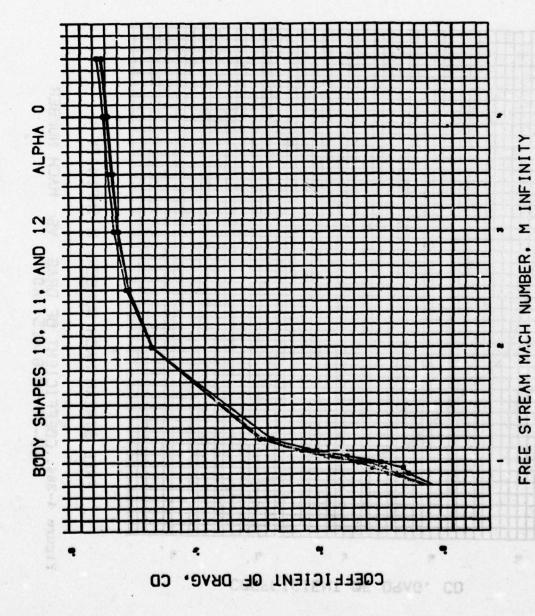
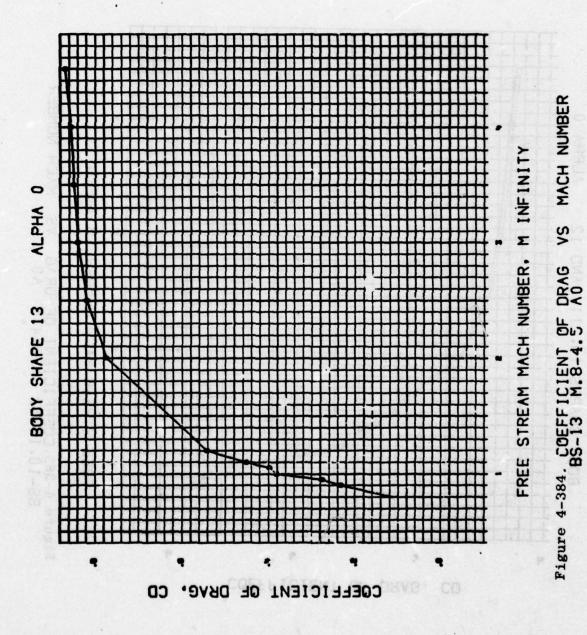


Figure 4-383.COEFFICIENT OF DRAG VS MACH NUMBER 85-10.11.12 M.8-4.5 A0



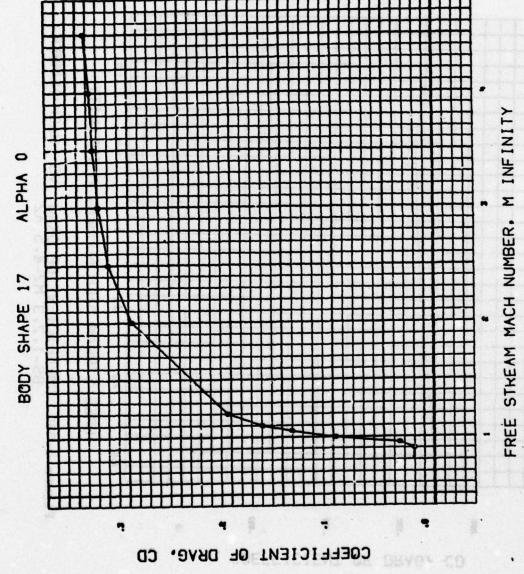
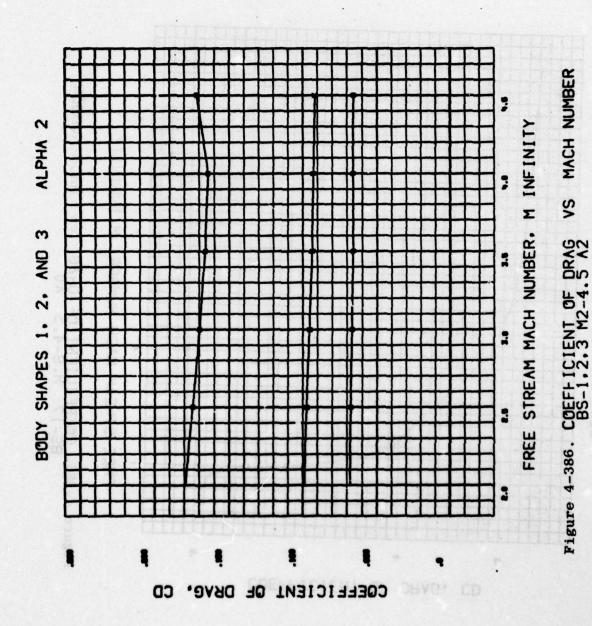


Figure 4-385. COEFFICIENT OF DRAG VS MACH NUMBER BS-17 M.8-4.5 A0



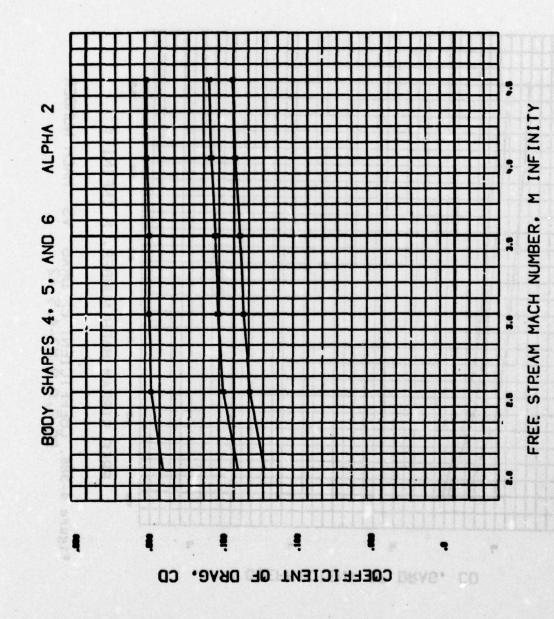


Figure 4-387. COEFFICIENT OF DRAG VS MACH NUMBER BS-4.5.6 M2-4.5 A2

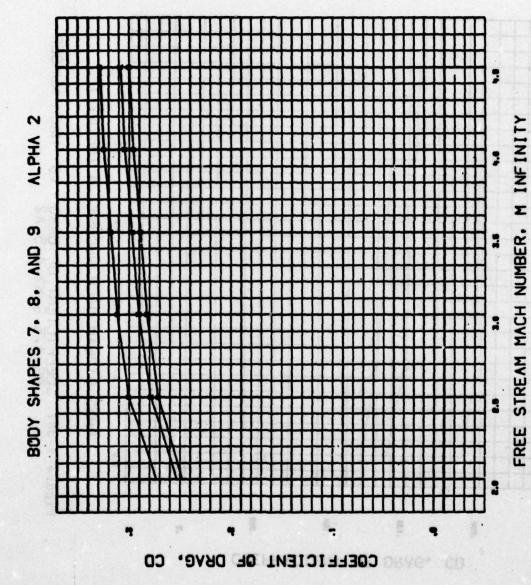
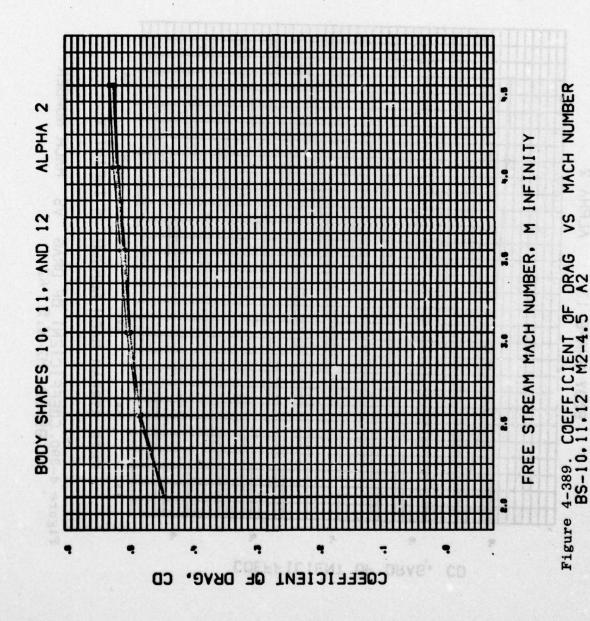
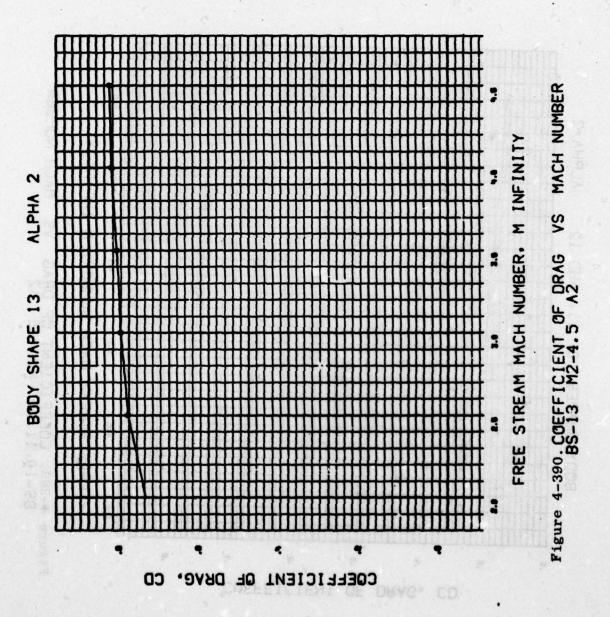
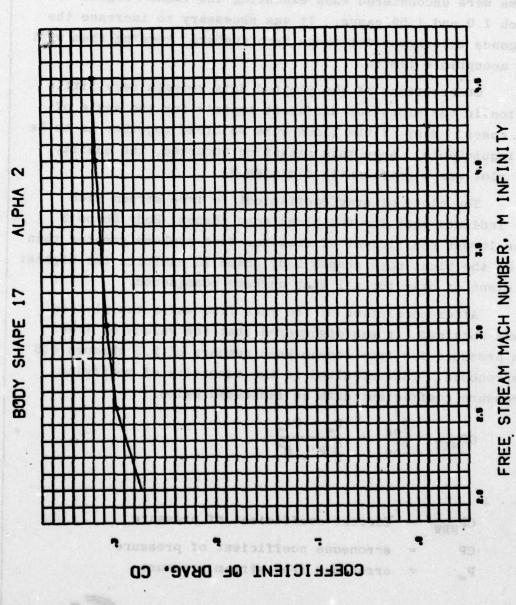


Figure 4-388. COEFFICIENT OF DRAG VS MACH NUMBER BS-7.8.9 M2-4.5 A2







initially this study was to include body shapes with

Figure 4-391. COEFFICIENT OF DRAG VS MACH NUMBER BS-17 M2-4.5 A2

5.0 RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Initially this study was to include body shapes with bluntness ratios of .2, .4, .6 and .8, and a fineness ratio of 1. However, these configurations would not execute in the 3D Program. It appears that the problem stems from where the shock wave attackes to the body for these shapes. Also, convergence problems were encountered when executing the TRANS Program for the Mach 1.0 and 1.05 cases. It was necessary to increase the convergence tolerances for these Mach numbers, keeping them well within acceptable limits.

Observations of the plotted data reveals very little variation in the plots for different theta's for the angle of attack cases. Many of the lines were so close together as to be indistinguishable. When this situation occurred, the quality of the plot was significantly diminished.

The plots of drag coefficient vs free stream Mach number indicate that for the blunt nose shapes, Body Shape 3 has the lowest coefficient of drag for Mach numbers greater than one. Of the blunt nose shapes Body Shape 13 exhibits the highest coefficient of drag for all Mach numbers considered.

After completion of the runs from which the plotted data was obtained, it was discovered that the values of free stream pressure for free stream Mach numbers of 2.5 through 4.5 were erroneous. This resulted in the necessity of modifying the pressure coefficient data as indicated below.

$$CP_{NEW} = \frac{P_{os}}{P_{os}'} + \frac{P_{\infty} - P'_{\infty}}{\frac{\alpha}{2} P'_{\infty} M^2}$$

where

CP_{NEW} = correct coefficient of pressure

CP = erroneous coefficient of pressure

P = erroneous free stream pressure



P' = correct free stream pressure

a = ratio of specific heats (1.4 for perfect gas)

M = free stream Mach number

The corrections were made to the CP data prior to plotting; however, the data from the computer printouts for the 3D and AC programs were not corrected.

Several programs had to be executed to obtain aero-dynamic data for each body shape configuration, depending upon the range of Mach numbers desired. A future effort to combine these programs may be feasible, allowing the calculation of all pressure coefficient and Mach data over any desired range of Mach numbers.



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- "Results of the Calculations of Supersonic Flow Fields About Spherical Capped Bodies of Revolution", J. L. Sims, NASA Technical Paper MTP-AERO-62-40, May 15, 1962.
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- 4. "The Addition of Secondary Shock Capability and Modifications to the GASL Three-Dimensional Characteristics Program, Part II: User's and Programmer's Manual", Gertrude Weilerstein, General Applied Science Lab, Inc., Technical Report No. 653, August 16, 1967.
- 5. "FORTRAN Program to Obtain Aerodynamic Coefficients From Pressure Distributions Output by the GASL Three-Dimensional Method of Characteristics Program", Alma S. Marks, U.S. Army Missile Command Report No. RD-TR-69-10, July 1969.



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